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COMPARISON TESTING OF AN ANALOG AND DIGITAL RANK-ORDER QUANTIZE--ETC(U)
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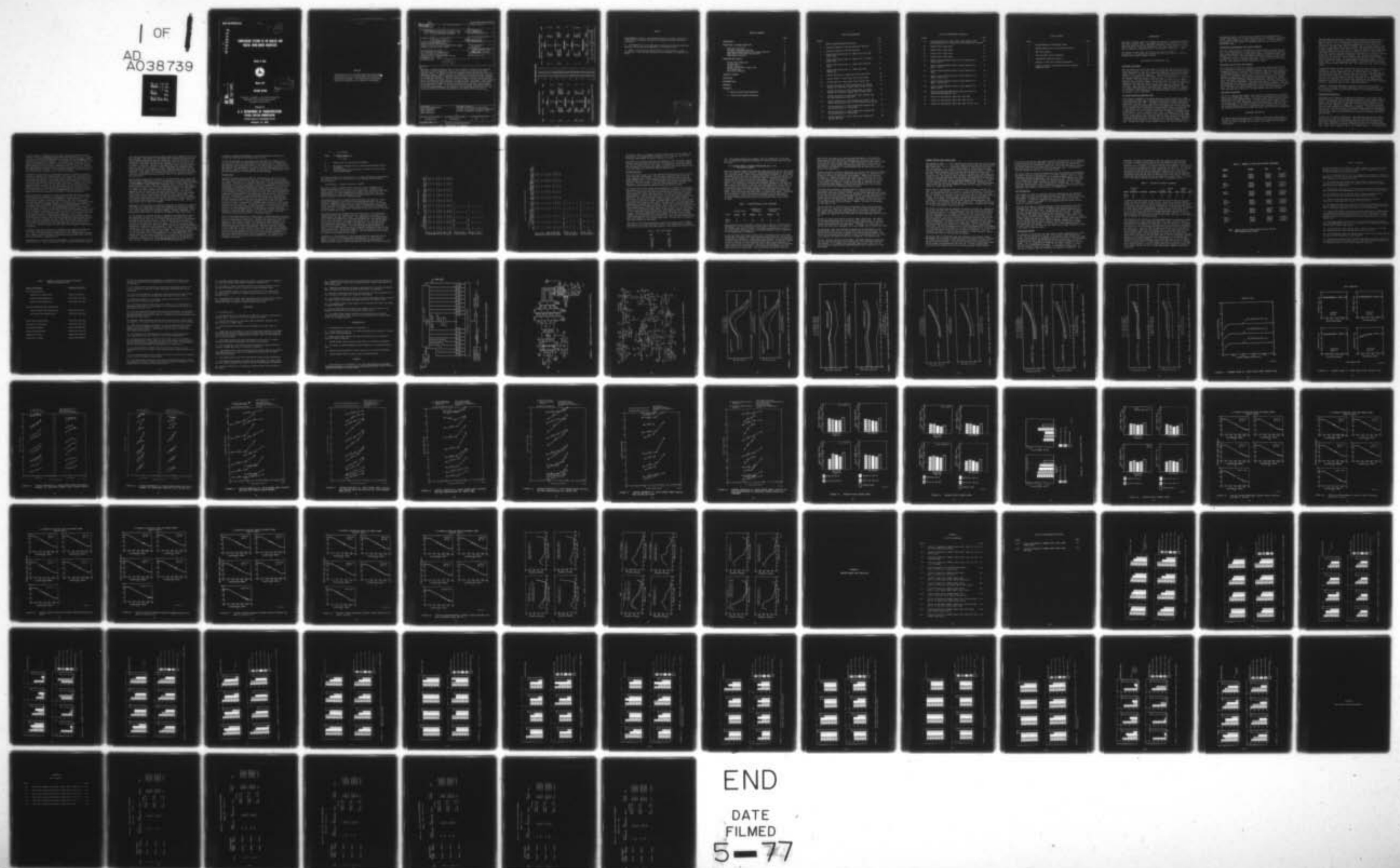

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COMPARISON TESTING OF AN ANALOG AND DIGITAL RANK-ORDER QUANTIZER

Martin H. Holtz

DEPARTMENT OF TRANSPORTATION UNITED STATES OF AMERICA

March 1977

INTERIM REPORT

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16. Abstract

The Radar Processing Subsystem (RPS) of the All-Digital Tracking Level System was employed to conduct comparative testing of an analog and a digital rank-order quantizer (ROQ). The analog unit was that designed by National Aviation Facilities Experimental Center (NAFEC) to replace an inferior version supplied under contract. The digital ROQ employed an eight-bit analog-to-digital converter and was furnished by the ARTS III contractor. The tests were performed for several system configurations, including two modifications to the digital (ROQ). Performance characteristics were based on percent noise regulation, target detection sensitivity, false target rates, isolated-hit stability, target hit distribution, and video select mapping, as achieved with the RPS. It was concluded that the digital ROQ produced equal to or better system performance, as compared to the analog ROQ provided that the automatic gain control and 50/50 modifications to the digital ROQ were employed.

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METRIC CONVERSION FACTORS

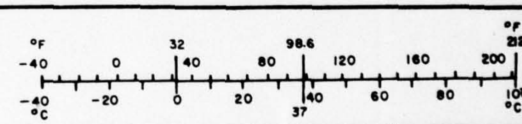
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, *Units of Weights and Measures*, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

Acknowledgment is made to the following personnel for their assistance in conducting the comparison testing of the analog and digital rank-order quantizers:

1. Leo Wapelhorst, for his assistance in design of the analog rank-order quantizer and the special modifications to the digital unit.

2. Messrs. Oliver Carlson, Richard Nelson, and David Rice, for their assistance in collection and reduction of data required to accomplish this effort.

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INTRODUCTION

This report contains analysis of comparative testing of an analog and a digital rank-order quantizer (ROQ). Performance characteristics were based on percent noise (P_N) regulation, target detection sensitivity, false target rates, isolated-hit stability, target hit distribution, and video select mapping, as achieved with the Radar Processing Subsystem of the All-Digital Tracking Level System.

The results of these tests will provide information necessary to justify procurement of the recommended equipment for inclusion in the Automated Radar Terminal System (ARTS) Package 1 System.

DESCRIPTION OF SYSTEMS UNDER TEST

RANK-ORDER QUANTIZERS.

Both the analog and digital ROQ's employ 24 noise taps and a video tap with a guard band adjacent to the video tap. The analog ROQ includes a delay line, an analog comparator for each tap, a center-tap amplifier, and an analog summing amplifier with a threshold comparator. The digital ROQ performs the ranking function by converting the analog input video to digital levels with an eight-bit analog-to-digital converter. Sampling times are controlled by a sample-and-hold circuit. The eight bits of data are serially shifted in eight parallel registers each 24 bits in length. The digital counts for each tap location are compared to the eight-bit contents of the video tap. The number of taps that are greater than the video tap are summed and compared to a digital ROQ threshold. Those sums that are greater than the ROQ threshold are outputted as an amplitude-quantized hit and subsequently sampled in time to accomplish hit placement. Block diagrams of the analog and digital ROQ's are depicted in figures 1 and 2, respectively.

THE RADAR PROCESSING SUBSYSTEM (RPS).

This system is composed of a hardware digitizer called the Radar Data Acquisition Subsystem (RDAS) and an operational program that resides in the ARTS III Input-Output Processor (IOP). The RDAS accepts basic timing information and analog video from the radar. Quantizers are employed to convert the analog video into amplitude-quantized binary hits and regulate the percent noise (P_N) to the selected value. Selection of the appropriate video is accomplished via a video switch and is controlled by the IOP. Discrete video selection is accomplished for an area 2 nautical miles (nmi) in range by 32 azimuth change pulses (ACP's). This is referred to as a zone. A mechanism for identifying clutter is provided by the clutter monitor function. The output of the video switch (either moving target indicator (MTI) or normal video) is processed by a hardware predetector that is provided to reduce the IOP loading. This hardware predetector provides only an indication of a potential target within a zone. It does not convey to the software detector the discrete range cell of

the potential target. The search for the range cell is accomplished by a software predetector prior to final detection, hit discrimination, and derivation of target azimuth via a center-of-mass technique. A detected target is then passed on to the tracker as a potential track, or as an update for an established track.

WESTINGHOUSE RADIOFREQUENCY TEST TARGET GENERATOR.

This test target generator is designed to provide simulated targets that have most of the characteristics of live targets such as azimuth-scanning modulation, target pulse-to-pulse scintillation, Doppler, and variable target radiofrequency (RF) levels. The test generator provided a coherent RF test target by sampling a portion of both the radar stable local oscillator (STALO) and coherent local oscillator (COHO) frequencies. The RF test target is injected into the radar system at the radar directional coupler.

AMPEX MODEL FR-950 VIDEO TAPE RECORDER.

The FR-950 video recorder is a wideband, rotary-head, magnetic tape recorder. It is designed to record and reproduce data with a band of 10 hertz (Hz) to 6 megahertz (MHz) on a direct frequency modulation (FM) carrier with sidebands not extending beyond 3 to 12 MHz. The recorder provides for record/reproduce channels (two wide-band channels and two auxiliary channels). The wide-band channels are employed to record analog video along with multiplexed triggers. The two narrow-band channels (auxiliary longitudinal channels) are used to record both analog and digital antenna position data, time code, voice annotations, and flutter compensation. The narrow-band data are frequency modulated and multiplexed via subcarrier frequencies on the auxiliary channels. The timebase stability of the recorded analog data is ± 15 nanoseconds (ns) over a full tape. The length of a data recording is 30 minutes for a dual-channel wideband recording, and 60 minutes for a single-channel wide-band recording.

INPUT/OUTPUT PROCESSOR.

The IOP is a general-type computer that provides for expansion of the computer memory core in 8,000-word modules. The system at National Aviation Facilities Experimental Center (NAFEC) airport surveillance radar (ASR-5) presently employs a memory size of 40,960 (40k) words. The IOP accepts azimuth words, target hit replies, and status information words from the beacon or radar data acquisition subsystems. It is used to perform statistical target detection, target tracking, display functions, and keyboard input functions from an operator, and outputs data functions to the ARTS III display and the online teletypewriter.

PROCEDURES AND RESULTS

The digital ROQ was interfaced with the RDAS by electrically substituting it for one of the existing analog units. The interface required line drivers to transmit hit data to the RDAS and to provide clock signals from the RDAS to the quantizer.

Since the quantizer employs an eight-bit analog-to-digital converter (D-A) it was deemed necessary to provide a function that would preserve the dynamic range of the D-A. This is attributed to the fact that if the level of the receiver noise is too low or the overall amplitute or direct current (d.c.) reference of the input radar signal fluctuates, then the digital samples could be a poor representation of the analog signal. The modification provided consisted of adding, under switch control, a nonlinear automatic gain control (AGC). A schematic diagram of the AGC circuit is shown in figure 3. Since initial tests indicated that poor P_N performance was achieved for low levels of receiver noise, the nonlinear amplifier was employed. The function was designed to provide gain as a function of input signal level, with small input signals resulting in maximum gain. The circuit also provides for a zero d.c. reference that is updated each sweep, and establishment of the maximum amplitude of the output signal. All self-regulating functions of this AGC circuit are based on samples obtained during radar dead time. This function was one of the variables tested.

A second modification included under switch selection was performed to the tap comparators. Recall that for each tap, the eight-bit count is compared to the video tap and the comparator outputs a logical "ONE" if the video tap is greater than the noise tap. However, there is a practical limitation that is introduced by ties which occur if the two counts are equal. To compensate for this inaccuracy, it was decided to utilize the "equal to, or greater than" output of the comparator for alternate tap positions and the remaining taps employed on the greater than outputs. This selectable function was also established as a system variable for most comparative testing.

A number of tests were conducted to provide sufficient data to develop a decision as to whether the digital performed as well as the analog ROQ. The tests and their results are described in detail in the following paragraphs of this document.

PERCENT NOISE REGULATION.

Preliminary tests conducted to establish P_N performance of the digital ROQ indicated that P_N regulation was extremely sensitive to input signal characteristics. Investigation into the problem resulted in findings that the clock signals that were employed to clock data into the logical functions were the same as the ones employed to sample data. The alert reader readily realizes that one cannot sample data as the data are changing. A modification was included to provide proper timing, and substantial improvement in P_N performance was achieved. This latter configuration will be the baseline for the digital ROQ performance when not employing the AGC or equal to or greater than 50/50 modifications.

The first set of results obtained were those employing several noise sources derived from a random noise generator. The tests were developed to provide information necessary to define P_N regulation as a function of sample rate, input level, employment of AGC and 50/50 modification, and input noise frequency. These results are presented in figures 4a and 4b for a 20-kilohertz (kHz) noise source and in figures 5a and 5b for a 500-kHz source. It is evident that

a 20-kHz source at a 500-millivolt (mV) input level with sampling rates in excess of 10^5 Hz, P_N increases rapidly above the theoretical value of 4 percent to a point at which it was approximately 6 percent and then decreases rapidly beginning at a frequency of 8×10^5 Hz. This results in a P_N of less than 1 percent at a sampling rate of 5×10^6 Hz. For a 100-mV input level with the AGC modification disabled, the shape of the overall response is the same as the 500-mV response, but the curves are shifted down by 1 to 2 percent. However, when employing the AGC modification, the 100-mV and 500-mV results are, for all practical purposes, the same. In all cases, employment of the 50/50 modification resulted in an increase in P_N of 0.5 to 0.75 percent.

Examination of the results for the 500-kHz noise source reveals that the P_N achieved is insensitive to sampling rates. The P_N achieved is within 0.5 percent of the selected value for an input level of 500-mV and 100-mV with the AGC modification enabled. The increase in P_N achieved with the 50/50 modification when employing the AGC modification was, for the most part, less than 0.5 percent and resulted in better overall performance. However, this increase was approximately 1 percent for the 100-mV level with no AGC modification. Results were also obtained, but are not presented in this document, for a 5-MHz noise source. These results were almost identical to those delineated for the 500-kHz source. It should be emphasized that P_N performance for all 500-mV inputs was not dependent on the state of the AGC modification.

Similar results were obtained for noise sources derived from radar receivers. Those depicting the response of the digital ROQ to ASR-5 MTI receiver noise for a selected P_N of 4 percent are presented in figures 6a and 6b. It is evident that the shape of the curves achieved for all test configurations, including the 100-mV set, were the same. More specifically, for sampling rates less than 10^6 Hz, P_N increased slightly for increasing sampling frequency. For rates greater than 10^6 Hz, the P_N achieved increased rapidly. At a rate of 7×10^6 Hz, the P_N rose to a value approximately 6 percent for an input level of 500-mV, with both the AGC and 50/50 modifications enabled. Each of the other configurations resulted in a lower P_N, with the case for no modification being the lowest. This difference was on the order of a 0.5-percent variation in P_N from one extreme to the other when employing a 500-mV signal. The corresponding curves for a 100-mV input indicate that with no modifications, the P_N was about 1 percent less than the configuration employing both modifications. The results achieved for ASR-7 linear MTI and linear normal receiver noise signals are depicted in figures 7a and b and 8a and b, respectively. It is evident that performance for these inputs was very similar to those achieved for the ASR-5, except that the normal video displayed slightly better performance.

In general, each video resulted in acceptable P_N performance when employing the AGC and 50/50 modifications within the practical sampling rates of 1 to 2 MHz. This performance was comparative to that achieved with an analog unit. However, previous testing of the analog unit indicated that it did not display sensitivity to sampling rates.

The next phase of testing involved establishment of the relationship of P_N and input noise level. These results were obtained for ASR-5 linear MTI receiver

noise while employing the analog and digital ROQ's with a sampling rate of 1/16 nmi (1.29 MHz). The results for the digital ROQ include the effect that the AGC and 50/50 modifications had on P_N regulation. The data available for the analog ROQ are presented in figure 9 for selected values of P_N of 4, 8, and 12 percent. The digital ROQ tests were conducted for a P_N of 4 percent and are shown in figure 10. Analysis of the analog ROQ curves indicated that for levels of input noise in excess of 100-mV (mean peak), the measured P_N was effectively equal to the theoretical value. Comparable performance was also achieved with the digital ROQ when utilizing both the 50/50 and the AGC modifications. There seems to be a tendency in the data, to this point, that indicates that the 50/50 modification has more effect on P_N regulation than the AGC modification.

Several weather samples were reproduced on the FR-950 video tape recorder and data defining P_N regulation in clutter environments for normal and MTI videos, and each digital ROQ configuration was plotted along with the analog ROQ results. It was decided to conduct these, and subsequent tests, for both 100-mV and 500-mV input noise levels. To reduce the amount of data and the time required to conduct the tests, a group of video tapes were selected to be employed for the 100-mV level and a second group for the 500-mV signals. It should be emphasized that the results for the analog ROQ were always collected for a 500-mV level, since that design does not employ an AGC circuit, and previous tests indicated that P_N performance suffered for levels below 100-mV. The reader should also be aware of the fact that the noise level was established for clear-air environments and that areas in proximity of weather clutter had reduced noise levels attributed to radar receiver recovery times. This is particularly true for ASR-5 MTI samples.

Examination of the P_N plots, as depicted in figures A-1 through A-16, indicate that there is no doubt that for those ROQ configurations that do not employ either the AGC or 50/50 modifications, P_N regulation is unacceptable. This is more clearly exemplified for the 100-mV samples. However, employment of the modifications does result in excellent performance for both noise levels.

For the purpose of providing a means of comparing the performance to that of the analog ROQ, the data for the analog ROQ and for the digital ROQ, with both modifications, were used to calculate the percent error for the measured P_N based on the theoretical values. These calculations were performed as a function of video type and input noise level. The percent error for each selected P_N was employed to obtain an average value for every weather sample. Subsequently, these results were employed to calculate the average error for all samples as a function of quantizer and video level. The results indicated that for a 500-mV level, the error values for normal video were 2.28 and 2.97 percent for the analog and digital ROQ's, respectively. The corresponding numbers for MTI video were 4.14 for the analog and 1.3 for the digital ROQ. The maximum error for the digital technique was 12.5 percent, and for the anlog, 25 percent. Results for the 100-mV data set with both the AGC and 50/50 modifications indicated that the average percent error for the digital ROQ was 3.91 and 3.7 percent for normal and MTI videos, respectively.

In general, comparative performance for the two quantizing techniques was achieved with the digital ROQ being slightly better.

In previous paragraphs, it was stated that there might be a tendency in the data to indicate that the 50/50 modification had more effect in improving P_N regulation than the AGC modification. The results for the clutter environment phase are also inconclusive for this particular aspect, since there are approximately the same number of situations for which each modification has the most effect. What can be said, however, is that the best configuration is the one that employs both the 50/50 and the AGC modifications.

ISOLATED HITS.

The Radar Processing Subsystem (RPS) was modified during evaluation of the system to include an isolated-hit function. An isolated hit is one which is not bounded by another hit at the same range call on the two adjacent neighboring sweeps. The purpose of isolated-hit function is to measure azimuthal correlation properties of hit data within a clutter environment and to utilize this information to accomplish second-threshold control and video selection. The method employed in the RPS is detailed in a report, written by the author of this document, entitled, "Test and Evaluation of the Radar Processing Subsystem of the All-Digital Tracking Level System." Briefly, the report delineates the progression of development of the isolated-hit function and test results that detail the performance of the second-threshold control and video selection functions. It should be pointed out that the RPS employs a technique that provides estimated isolated-hit counts for each zone, a zone being defined as an area 2 nmi by 32 ACP's. During the evaluation of the RPS, data were collected to permit a comparison of estimated counts and actual counts derived using external test counters. In addition, tests were conducted to determine the effect that P_N had on isolated-hit performance. It was concluded that an actual count, while employing a P_N of 32 percent, was the most effective approach. Due to the above results, it was decided to conduct the digital and analog ROQ comparison tests primarily for a P_N of 32 percent, and actual isolated-hit counts would be used for comparison purposes.

Prior to presenting the results of these tests, it seems appropriate to discuss the use of the isolated-hit counts so the reader may have a better understanding of the importance of these tests. Briefly, the isolated-hit count is employed on a zone basis to develop the appropriate second threshold to be employed in each individual zone. The criterion for video selection was established from previous evaluations which unequivocally proved that MTI should be employed in clutter environments. Therefore, the RPS is designed to select MTI video in the presence of clutter and to apply second-threshold control within the boundaries of the clutter map. Now that the basic ground rules have been established, the specifics of the function implemented to perform second-threshold control will be delineated. The isolated hits are employed to derive the required second-threshold value according to the following relationship:

$$T = T_o + A(C_o - C)$$

where: $A = \dfrac{\text{Window Length} - T_o}{C_o - C_{WL}}$

T_o - Base T_L used in clutter-free environment

C_o - The value of isolated hits for which second-threshold control is enabled.

C_{WL} - Value of isolated hit for which T is forced to a value equal to the window length.

It should be evident that this function is a simple straight-line relationship. The theoretical value of isolated hits for uncorrelated returns within a zone is given by:

$$\text{Isolated Hits} = (\text{Range cells/zone})\ (1-P_N)^2 P_N$$

With this in mind, it should be clear that the value of isolated hits is directly proportional to the value of P_N in each zone. Although P_N was fairly constant for the analog ROQ and the digital ROQ with the AGC and 50/50 modifications, for a more comprehensive analysis of the effect that the digital ROQ has on system performance, all configurations of the quantizer will be presented in this and subsequent tests.

The isolated-hit count for sample zones was obtained for each scan. These counts were employed to derive curves depicting the performance of each quantizer configuration for values of 4- and 32-percent noise. Since these curves are numerous in number and would occupy a significant portion of this report, they are not presented at this time, but the results are summarized in tabular form. For those readers interested in the actual curves, the author may be contacted for a copy.

The tabular results are presented for the average value of the isolated-hit counts obtained for each weather sample as a function of P_N, digital ROQ configuration, and input noise level. Also summarized is the average percent error, which was obtained by calculating the percent that the standard deviation of the isolated-hit count was of the average count. This was performed for each zone for each of the conditions under test. The individual zone percentages were subsequently used to calculate an average percentage for that particular weather sample. This was obtained by merely summing the results of each zone having a particular quantizer configuration, and calculating the mean value. The average number of hits is presented in table 1, and the percent error is delineated in table 2. Both the normal and MTI isolated-hit results are presented in each table.

Examination of the average-hit counts indicates that the variations did not seem to be a function of the quantizer configuration for input levels of 500-mV. However, for the 100-mV level the quantizer configuration not employing either the AGC or 50/50 modifications resulted in the lowest isolated-

TABLE 1. AVERAGE NUMBER OF ISOLATED HIT COUNTS

I. 500 mV

Sample	DIGITAL ROQ 32% P_N 50/50 In AGC In	50/50 Out AGC Out	50/50 Out AGC In	50/50 Out AGC Out	Analog ROQ 32% P_N	DIGITAL ROQ 4% P_N 50/50 In AGC In	50/50 In AGC Out	50/50 Out AGC In	50/50 Out AGC Out	Analog ROQ 4% P_N
WW 29 Normal	155.41	140.98	159.52	145.76	156.74	14.27	20.48	19.55	11.52	28.14
WW 29 MTI	168.42	169.5	177.12	169.6	171.29	35.52	34.12	34.58	34.14	46.49
COMP No. 1 Normal	190.55	183.15	184.15	184.1	175.5	36.25	30.85	30.34	32.27	42.9
COMP No. 1 MTI	184.43	176.2	172.92	173.82	169.97	34.81	35.61	32.33	32.89	43.49
4/3/75 Normal	197.08	195.55	203.59	192.54	210.2	39.66	40.82	29.44	27.65	44.13
4/3/75 MTI	182.32	185.03	195.56	193.32	215.41	45.16	47.31	49.37	44.3	37.62
4/15/75 a.m. Normal	217.07	214.94	210.73	201.79	221.12	38.22	38.87	36.18	31.53	46.83
4/15/75 a.m. MTI	202.03	199.06	196.17	202.66	227.2	47.85	45.05	45.19	47.24	36.24
3/12/75 Normal	219.75	222.68	219.65	208.65	230.02	38.92	37.97	33.33	31.71	44.69
3/12/75 MTI	202.47	204.68	202.12	188.5	206.7	36.04	38.03	36.82	31.61	47.15
II 100 mV 32% P_N										
7/14/75 a.m. Normal	223	216	216	136	191					
7/14/75 a.m. MTI	21	205	216	188	221					
4/15/75 p.m. Normal	223	219	218	195	214					
4/15/75 p.m. MTI	220	217	214	193	218					
III 500 mV 32% P_N										
7/14/75										
7/14/75 a.m. Normal	230	221	225	221	216					
7/14/75 a.m. TI	220	223	203	173	212					
4/15/75 p.m. Normal	224.5	217	217	202	213					
4/15/75 p.m. MTI	219	221	218	214	218					

TABLE 2. AVERAGE PERCENT ERROR OF ISOLATED HIT COUNTS

I. 500 mV ROQ

	Sample	DIGITAL ROQ 32% P_N 50/50 In AGC In	DIGITAL ROQ 32% P_N 50/50 In AGC Out	DIGITAL ROQ 32% P_N 50/50 Out AGC In	DIGITAL ROQ 32% P_N 50/50 Out AGC Out	Analog Rank 32% P_N	DIGITAL ROQ 4% P_N 50/50 In AGC In	DIGITAL ROQ 4% P_N 50/50 In AGC Out	DIGITAL ROQ 4% P_N 50/50 Out AGC In	DIGITAL ROQ 4% P_N 50/50 Out AGC Out	Analog Rank 4% P_N
WW29 Normal	9.2	9.6	6.4	10.6	6.35	37.0	27.8	32.4	56.2	22.25	
WW29 MTI	6.2	6.0	5.2	6.8	5.05	9.6	11.2	13.2	11.2	10.65	
COMP No. 1 Normal	5.0	5.8	5.6	6.2	5.1	12.6	15.8	14.2	13.6	13.5	
Comp 1 MTI	7.4	6.8	6.6	6.0	4.9	20.6	14.6	13.6	12.0	13.25	
4/3/75 Normal	4.6	6.2	7.2	5.4	6.5	16.6	12.8	19.0	22.0	16.2	
4/3/75 MTI	5.4	6.6	6.0	4.6	5.7	16.8	13.0	12.8	18.0	13.78	
4/15/75 a.m. Normal	6.6	6.0	4.4	4.4	5.45	13.8	14.8	15.8	21.8	16.35	
4/15/75 MTI	6.4	6.0	6.8	5.6	6.25	15.2	13.2	13.6	14.6	14.65	
3/12/75 Normal	4.0	4.6	4.8	4.4	5.08	12.8	13.4	14.6	16.8	14.25	
3/12/75 MTI	4.8	3.2	5.2	5.2	6.08	22.4	13.8	15.2	20.2	13.75	
II 100 mV 32%											
7/14/75 a.m. Normal	5.43	5.4	5.14	9.6	3.58						
7/14/75 a.m. MTI	5.25	7.23	5.25	5.97	4.52						
4/15/75 p.m. Normal	6.17	5.33	5.0	6.5	5.2						
4/15/75 p.m. MTI	5.5	5.3	5.2	4.3	4.5						
III 500 mV 32%											
7/14/75 a.m. Normal	5.68	6.94	5.34	5.5	5.13						
7/14/75 a.m. MTI	6.1	5.51	5.45	8.3	3.5						
4/15/75p.m. Normal	7.8	7.3	4.8	4.8	5.6						
4/15/75 p.m. MTI	4.6	4.4	5.3	6.1	3.8						

hit counts. There is a tendency of the 4-percent counts for the digital and analog units to be significantly different. This is not the case for the 32-percent noise sample for which no pattern is present.

The percent error results show that the 4-percent P_N hits definitely produce a greater error than that obtained with a 32-percent P_N. It is also evident that for the higher values of P_N, there is no significant difference between the performance of the analog and digital quantizers for either normal or MTI videos when employing the digital ROQ with modifications.

PERCENT DETECTION.

These tests were derived to provide information defining detection of targets in a clutter-free environment. The tests were conducted using an RF test target generator that produced targets having a beam-modulated pattern at various signal levels. Since statistical detection is based on range cells, there are positions relative to cell boundaries that produce optimum-to-poor detection. For this reason, it was felt that optimum-placed and non-stationary targets should be employed during the detection tests.

The targets that moved in range were established in a fashion that provided radial motion at a rate that was not a multiple of the digital clock frequency. This was accomplished by employing the moving-target feature of the RF test target generator. Three rings of targets, each ring containing 32 targets, were employed to obtain a good sample size. The velocity of each ring was adjusted to the first optimum MTI velocity for the radar being employed. The ASR-7 radar set employed a stagger trigger sequence, as shown in table 3. The resulting video was recorded on an Ampex model FR-950 video tape recorder, along with radar triggers, ACP's, ARP's, and time code. The video tapes were subsequently reproduced and processed by the RPS with the analog and digital ROQ's configured for various test modes. These tests were then conducted using fixed position targets optimally placed within a range cell. To reduce the number of variables during these tests, it was decided to compare performance of the various digital ROQ configurations while employing only stationary targets. Detection capabilities of the digital and analog functions were compared for both stationary and moving targets. The test tapes contained target levels between zero and 15 decibels (dB) above receiver minimal discernible signal (MDS) for each receiver under test. For each level, 15 scans of data were collected in 1-dB steps.

The number of test targets detected by the RPS was obtained via a software modification to the IOP operational program. The average number of targets detected for each target level were printed on the teletype at the end of each

TABLE 3. ASR-7 PRF SEQUENCE

PRT	PRF
1403	713
953	1050
893	1120
853	1173
1053	950
833	1200

run. The program provided for automatic start and termination of each data set. The data were subsequently employed to calculate percent detection (P_D) as follows:

$$P_D = \frac{\text{Average number of targets detected per scan}}{\text{96 possible targets}} \times 100$$

Detection and false target rate tests were conducted during the test and evaluation of the RPS to establish the best compromise between detection, false target rate, and IOP loading. These results are detailed in reference 1. Of primary consideration was the number of predetections within clutter environments. The sets of parameters that were selected were based on an approximate 10^{-5} false target rate in a clear (clutter-free) environment. The actual parameters employed for the previous tests and those described herein are listed in table 4. The difference in predetection threshold required for the ASR-5 and ASR-7 radars is attributed to the fact that the antenna rate for the ASR-5 is 15 revolutions per minute (rpm) and that for the ASR-7 was 12.75 rpm. This, along with any pulse repetition frequency (PRF) difference between the two radars, would result in a different number of expected hits per antenna beam width. This would affect both detection of true and false targets. Therefore, it was necessary to adjust the detection parameters and the beam shape of the test targets. The pattern of the test target generator was adjusted to provide a Gaussian two-way pattern as would result from a point target in space.

TABLE 4. DETECTION/FALSE TARGET PARAMETERS

Radar	Percent Noise		Predetection Threshold		Final Detection Threshold	
	Normal	MTI	Normal	MTI	Normal	MTI
ASR-5	8	4	8	10	6	6
ASR-7	8	4	9	11	6	6

Addressing the results obtained to define P_D as a function of (1) the type of ROQ employed, (2) the configuration of the digital ROQ, and (3) the type of test target used, flying or fixed. The results are presented as a plot of P_D versus percent false target (P_{fa}) rates which permits a direct comparison of the configuration in question.

The flying versus fixed target results will be discussed first, since these results were consistent with those obtained during the RPS test and evaluation as described in reference 1. These tests were conducted with the digital ROQ configured with the AGC and 50/50 modifications enabled. The results, figures 11 and 12, indicate that for normalized false target rates, detection of a normal video, fixed, optimum-placed target was approximately 2 dB better than that achieved for flying targets. This measure of improvement was on the order of 0.5 dB for linear MTI. This is attributed to the fact that the

ASR-7 MTI is the product of a digital system followed by a D-A converter. These digital circuits introduce a sampling loss, since the clock rate of the MTI system is not the same rate or synchronized with the RDAS timing logic. The results for fixed targets indicate that an increase in performance of approximately 2 dB was achieved by employing normal video in place of MTI. These results are identical to those obtained with the analog ROQ during the RPS test and evaluation.

Detection losses for the ASR-7 digital MTI at a 100-mV noise level were approximately 0.75 dB for the digital ROQ without modifications, as compared to the results for which the modifications were enabled. These curves are shown in figure 13. Similar performance was achieved for levels less than 4 dB above MDS when employing linear normal video. However, for levels in excess of 4 dB, numerous range splits occurred which made it impossible to obtain a valid P_D-P_{fa} relationship. Neither this problem nor the detection loss was encountered when employing a 500-mV input noise level or with a 100-mV level with the AGC and 50/50 modifications enabled.

Tests were then conducted to determine which of the two modifications had the greatest effect on P_D-P_{fa} performance. To accomplish this goal, ASR-7 digital MTI test targets within a 100-mV receiver noise background were applied to the digital ROQ for the following configurations: (1) the 50/50 modification disabled and the AGC modification enabled, and (2) the 50/50 modification enabled and the AGC modification disabled. The results of this test are depicted in figure 14 and indicate that the AGC modification was more effective in producing greater P_D-P_{fa} performance. However, the level of improvement was less than 0.5 dB.

The test results for the direct P_D-P_{fa} comparison tests of the analog and digital ROQ's are depicted in figures 15 and 16 for linear normal and digital MTI, respectively. The tests were conducted for stationary targets, with the digital ROQ modifications enabled, and the noise levels were adjusted for 100-mV for digital ROQ tests and 500-mV for those performed with the analog ROQ.

Analysis of these curves indicate that for linear normal video, the analog ROQ produced approximately a 0.5 dB better P_D-P_{fa} performance. The results for the digital MTI video were just the opposite, with the digital ROQ being superior by approximately the same amount. Therefore, it is the author's opinion that there is no meaningful difference between the two design techniques.

Two additional tests were conducted to provide (1) the performance of the analog ROQ for input levels of 100 and 500-mV and (2) the effect that the second-threshold control has on targets in a clutter-free environment. The results for the analog ROQ are shown in figure 17 and indicate that the 100-mV level produced less than a 0.5-dB loss, as compared to the 500-mV level.

The test results obtained with and without the second threshold-control function are presented in figure 18 for digital MTI, with the digital modification enabled. It is evident from the curves that a loss of only a 0.5 dB was introduced by employing the second-threshold control function in a clear environment.

WEATHER CLUTTER FALSE TARGET RATES.

The purpose of these tests was to determine the false target rate (P_{fa}) achieved when processing various weather clutter samples derived from both the ASR-5 and ASR-7 radar sets. Previous evaluations resulted in conclusive results that MTI video produces a significantly lesser number of false targets in weather clutter environments than normal video for the same clutter sample. Therefore, all test results presented in this document were obtained while employing MTI video. The RPS was configured for a P_N of 4 percent and a basic detection threshold of 6. The method of second-threshold control employing isolated-hit counts, as previously detailed under the topic, "Isolated Hits," was employed to select the appropriate value of second lead-edge threshold (T_L). It should be pointed out that this function performed regulation by sampling hits for a P_N of 4 percent and not the optimum value of 32 percent. This was necessary, since the RPS does not provide adequate storage for the increased data load yielded by a high value of P_N.

Recall that for isolated-hit counts less than CW_o but greater than CW_L, the value of the second threshold is based on a linear relationship. For isolated-hit count greater than CW_o the base T_L is employed, and for counts less than CW_L, the threshold is forced to a value equal to the size of the basic detection window. In the tests described herein, the window size was maintained to a length of 17 sweeps. The parameters employed for these tests were those resulting from optimization tests conducted during the RPS evaluation, and were 27 and 5 for parameters CW_o and CW_L, respectively. The ASR-5 data having an antenna rotation rate of 15 rpm, were obtained with a predetection threshold of 11, since the antenna rate was 12.75 rpm.

The results of these tests are depicted in figures 19 through 22. Examination of the data indicates that false target rates achieved with the analog device were generally equal to, or slightly greater than, any of the various digital ROQ test configurations. It should be pointed out that the abscissa of the plots is logarithmic, and the differences in P_{fa} may be greater than one may initially realize. The case for which the 50/50 modification is disabled and the AGC function enabled seems to produce fewer false targets than the converse configuration. The situation for which both modifications were disabled generally resulted in the lowest false target rate. However, as discussed in the preceding section, there was a corresponding loss in target detection sensitivity. The loss delineated was for a clear environment and is anticipated to be even greater in the vicinity of a clutter environment due to the decreases in isolated-hit counts resulting from the weather correlation. Thus, the lead-edge thresholds in zones in close proximity of clutter should be significantly greater than in a clutter-free environment.

The general range of thresholds that were employed in each weather clutter environment may be derived by recalling that in the section for which isolated hit results were discussed, it was stated that isolated-hit count data for several zones was available. The data were collected for 10 consecutive scans and an average count was derived for each zone. If these average values are placed on the theoretical curve for second-threshold control based on

the values of CW_0 and CW_L, then general behavior characteristics of the threshold control function could be developed. This is exactly what has been accomplished to derive the curves of figures 23 through 29. Observing these results for the various digital and the analog ROQ's, one can see that the range of threshold values was within the linear portion of the threshold curve. This indicates that the function was not over- or undercontrolling.

The several zones for which the isolated-hit data were obtained and subsequently employed to derive the threshold plots do not show a definite pattern to enable a statement relative to the behavior of the second-threshold control as a function of digital ROQ configuration. This is also true when comparing the results of the analog ROQ to those achieved with the digital unit. The most important factor is that with either the analog or digital technique the false target rates were within one-half order of magnitude of a 1×10^{-5} rate. It is postulated that the decrease in false target rates experienced with the modifications disabled is the result of the drop in P_N as aforementioned.

HIT DISTRIBUTION.

This category of tests was conducted firstly to determine the distribution of false target hits that resulted primarily from MTI weather clutter returns, and secondly, to determine the distribution attained from the total surveillance environment. It should be recognized that any real targets are included in the data. However, the number of true targets within the weather clutter areas are considered neglible.

Data were collected for the analog ROQ and for the various digital ROQ test configurations. Several samples of weather clutter were derived from both the ASR-5 and ASR-7 radar sets. The results were analyzed graphically as a plot of the percentage of total targets having each hit count. In general, the shape and the percentage values of each curve were similar. Therefore, only a few of the samples were selected to be presented. These results are shown in figure 30 for an ASR-5 sample, and corresponding results for a couple of ASR-7 samples are depicted in figures 31 and 32. The hit counts were obtained with the second-threshold control function enabled. Examination of these results indicate that the general shapes of the distribution for the analog and digital ROQ's are similar. For the most part, the predominant number of false targets had hit counts of 12 or less, with a slight increase occurring at the 20-hit or more data point.

VIDEO SELECT MAPPING.

The technique for performing the video select function recommended as a result of the test and evaluation of the RPS is one based on normal isolated-hit counts. This technique was developed to utilize the normal isolated-hit counts to automatically select the appropriate video on a zone basis. The established criterion is that MTI video is selected for all zones for which clutter is sensed. This is accomplished by comparing the normal isolated-hit count for each zone to an established threshold. If the count is equal to, or less than the threshold, then a scan counter is incremented by some value. If the count is greater than the threshold, the counter is decremented. The

threshold, increment, and decrement values are software system parameters which were established during the RPS test and evaluation and are listed in table 4. A scan counter exists for each zone and is updated each scan until the count is equal to, or greater than the scan threshold. Upon satisfaction of the scan threshold, MTI video is selected for that zone. This process is continuous, thus updating the video select map each scan. There is also provision to extend the map in range and/or azimuth by one or more zones. This extension process is termed "soaking." The necessary soaking parameters established during the RPS test and evaluation were three zones in range for ranges less than 20 nmi and one zone in range for all other ranges. A complete list of parameters employed during these tests is presented in table 5.

TABLE 5. ISOLATED-HIT MAPPING PARAMETERS

Radar	Isolated-Hit Threshold	Increment	Decrement	Scan Threshold	Sweeps Per Zone	Range	Soaking Added Range	Azimuth
ASR-5	29	1	1	10	31	1	2	1
ASR-7	31	2	1	7	31	1	2	1

It should be recognized that the video selection function requires two quantizers, one each for normal and MTI videos. Since only one digital ROQ was available, it was decided to repeat the tests twice, once with the digital ROQ in the normal video position and the analog ROQ in the MTI position and then with the two quantizers interchanged. In this way, it was possible to determine if either one of these configurations resulted in fewer false target rates. It is not possible to determine if improved performance was attributed to better clutter recognition or false target regulation. However, it has been established that the false target rates within clutter were less for the digital ROQ, as compared to the analog version.

Addressing the test results for various weather samples as tabulated in tables B-1 through B-6, it can be seen that lower false target rates were generally achieved when the digital ROQ was employed as the MTI quantizer. The average improvement for all samples was calculated to be 23.6 percent when comparing the results for only the digital ROQ with modifications to those achieved with the analog unit. There was only one sample for which a loss of 5.8 percent was encountered. Since the false target rates for the digital ROQ were less for both false target tests for which MTI was forced and for these video select mapping tests, it seems reasonable to assume that the mapping function performed at least equally as well with either of the two quantizing techniques. Further, if the digital/analog ROQ data are compared to the configuration employing only analog quantizers, it is evident that four of the six samples produced more favorable performance when the digital ROQ was used to replace one of the analog units. For the readers convenience, a summary of the video select mapping results for those configurations which employed an analog ROQ and a digital ROQ with the AGC or 50/50 modifications enabled is presented in table 6.

TABLE 6. SUMMARY OF VIDEO SELECT MAPPING PERFORMANCE

Sample	Normal	MTI	FAR
ASR-5 WW-29	Analog	Digital	4.57×10^{-5}
	Digital	Analog	5.07×10^{-5}
	Analog	Analog	5.78×10^{-5}
ASR-7 3/12/75 P.M.	Analog	Digital	3.21×10^{-5}
	Digital	Analog	5.65×10^{-5}
	Analog	Analog	3.81×10^{-5}
ASR-7 4/3/75	Analog	Digital	1.75×10^{-5}
	Digital	Analog	2.28×10^{-5}
	Analog	Analog	2.3×10^{-5}
ASR-7 4/15/75 A.M.	Analog	Digital	2.17×10^{-5}
	Digital	Analog	3.25×10^{-5}
	Analog	Analog	2.55×10^{-5}
ASR-7 4/15/75 P.M.	Analog	Digital	5.2×10^{-5}
	Digital	Analog	4.9×10^{-5}
	Analog	Analog	2.52×10^{-5}
ASR-7 7/14/75 A.M.	Analog	Digital	5.44×10^{-5}
	Digital	Analog	5.95×10^{-5}
	Analog	Analog	4.59×10^{-5}

NOTE: Digital data are those obtained with the AGC and 50/50 modifications enabled.

SUMMARY OF RESULTS

For the convenience of the reader, an overall summary of the results of the comparison testing of the analog and digital ROQ's is presented in table 7. The detailed results are delineated below:

1. A 1- to 2-percent drop in the actual digital ROQ percent noise (P_N) was experienced for 20 kHz of test noise when disabling the automatic gain control (AGC) function with a 100-mV input level.

2. The digital ROQ P_N achieved with a 500-kHz noise source was within 0.5 percent of the selected value for either a 500- or 100-mV level while employing the AGC modification.

3. The increase in the P_N for the digital ROQ resulting from enabling the 50/50 modification, was approximately 1.0 percent for noise levels of 100-mV.

4. The digital ROQ P_N for receiver inputs increased rapidly from the theoretical value as the sampling rates increased above 10^6 Hz.

5. Previous tests indicated that the analog ROQ did not display a sensitivity to sampling rates between $3x10^5$ and $1x10^7$ Hz.

6. For levels of input noise in excess of 100-mV, the digital ROQ with the AGC and 50/50 modification was effective in controlling P_N to the theoretical value. Comparative performance was achieved with the analog ROQ.

7. Normal video weather clutter inputs having approximately a 500-mV noise level produced average percent noise errors of 2.28 and 2.97 percent of the theoretical values for the analog and digital units, respectively. Corresponding results for MTI video were 4.14 for the analog ROQ and 1.31 for the digital unit.

8. The average percent error of P_N for the digital ROQ with both the AGC and 50/50 modifications was 3.91 and 3.7 percent of the theoretical value for normal and MTI videos, respectively.

9. The isolated-hit counts did not seem to vary as a function of digital ROQ configuration for input receiver noise levels of 500 mV.

10. The isolated-hit counts for 100-mV receiver noise levels dropped when the ROQ AGC and 50/50 modifications were disabled.

11. The analog and digital ROQ's produced comparable isolated-hit counts for a selected P_N value of 32 percent for all noise levels tested, provided that the digital ROQ AGC and 50/50 modifications were employed.

TABLE 7. SUMMARY OF DIGITAL AND ANALOG RANK-ORDER QUANTIZER COMPARISON TESTS

Type of Performance	Comparison Indicator
Percent Noise Control	
Sensitivity to Sample Rate	Analog ROQ Superior
Receiver Noise Regulation	Effectively the same
Weather Clutter Regulation	Effectively the same
Clear-Air Detection/False Target Rates	
Without Digital ROQ Modifications	Analog ROQ Superior
With Digital ROQ Modifications	Effectively the same
Weather False Target Rates	Effectively the same
Isolated-Hit Performance	Effectively the same
Video Select Mapping	Digital ROQ Superior
Target Hit Distribution	Effectively the same
Long-Term Stability	Digital ROQ Superior
Simplicity of Design	Digital ROQ Superior

12. Within a weather clutter environment, the isolated-hit counts for the digital and analog ROQ's were significantly different for a selected P_N of 4 percent.

13. The percent error of isolated-hit counts was significantly greater for a P_N of 4 percent as compared to those experienced when employing a P_N of 32 percent.

14. For a P_N of 32 percent, no meaningful difference between normal and MTI isolated-hit performance was measured for either normal or MTI videos.

15. Detection sensitivity of stationary targets was increased by 2 dB by employing normal video in place of MTI.

16. A stationary target within normal video produced a 2-dB improvement in detection as compared to a moving target. The corresponding improvement for digital MTI was only 0.5 dB.

17. With the digital ROQ AGC and 50/50 modifications disabled, an approximate loss in target detection sensitivity of 0.75 dB was experienced for digital MTI inputs having a noise level of 100 mV as compared to the configuration which employed the modifications.

18. Numerous range splits were incurred with normal video at a 100-mV level when applied to the digital ROQ with the AGC and 50/50 modifications disabled.

19. There was no meaningful difference in clear-air-detection false target (P_D-P_{fa}) performance between the analog and digital ROQ's provided that a 500-mV level was employed or a 100-mV level with the digital ROQ AGC and 50/50 modifications enabled.

20. The digital ROQ AGC modification was effective in producing greater P_D-P_{fa} performance than that yielded by only the 50/50 modification.

21. Percent detection versus clear-air false target rates for the analog ROQ was approximately 0.5 dB superior to that of the digital ROQ with the AGC and 50/50 modifications enabled when employing normal video. The digital MTI results were just the opposite by approximately the same amount.

22. The analog ROQ with a 100-mV input level produced a P_D-P_{fa} loss of approximately 0.5 dB as compared to that achieved with a 500-mV receiver noise level.

23. The second-threshold control function introduced a P_D-P_{fa} loss of approximately 0.5 dB in a clear-air environment.

24. The false target rates for the analog ROQ resulting from weather clutter were generally the same or greater than those resulting from employment of the digital ROQ with the AGC and 50/50 modifications.

25. A weather clutter false target rate within a one-half order of magnitude of 1×10^{-5} was achieved with either the analog or digital ROQ.

26. The range of second thresholds imposed by the second-threshold control function was between 6 and 15 for both the analog and digital ROQ's.

27. The predominant number of weather false targets, for both ROQ's, had hit counts of 12 or less, with a slight increase occurring at the 20-hit or more data point.

28. The weather false target rates experienced with the video select function were approximately 23 percent lower when employing the digital ROQ to process MTI video as compared to employing the analog units.

CONCLUSIONS

It is concluded that:

1. The digital ROQ P_N for 500 kHz and a 5-MHz noise source is insensitive to sampling rates. This is not true for a 20-kHz noise source.

2. The AGC modification to the digital ROQ successfully regulates input noise sources to a usable level.

3. The digital ROQ 50/50 modification increases P_N for input level of 100-mV.

4. Comparative P_N performance for the two quantizing techniques is achieved with either the analog or digital methods, provided that the digital ROQ AGC and 50/50 modifications are employed and the input levels for the analog ROQ are in excess of 100-mV.

5. The digital ROQ AGC and 50/50 modifications are necessary to achieve acceptable isolated-hit performance for 100-mV noise sources.

6. The isolated-hit counts achieved with the analog and digital ROQ's are similar, provided that a P_N of 32 percent is employed.

7. Unacceptable split rates were experienced for normal video at the 100-mV level when applied as an input to the digital ROQ with the AGC and 50/50 modifications disabled.

8. The digital ROQ AGC and 50/50 modifications improve P_D-P_{fa} performance.

9. The digital ROQ provides acceptable P_D-P_{fa} performance for noise levels as low as 100-mV, provided that the AGC and 50/50 modifications are employed.

10. Detection sensitivity is improved by applying normal video in place of MTI video.

11. A measurable improvement in P_D-P_{fa} performance is attained by employing a fixed target in place of one that is moving for ASR-7 normal video and not for ASR-7 digital MTI.

12. Comparative performance in P_D-P_{fa} is achieved with the analog and digital ROQ's, provided that the AGC and 50/50 modifications are employed.

13. The loss in detection sensitivity introduced by the second-threshold control function is not severe in a clear-air environment.

14. The threshold values that result from the second-threshold control function in weather clutter fall within the linear portion of the control curve.

15. An acceptable weather false target rate is attained with either the analog or digital ROQ method.

16. The hit distribution of weather false targets is very similar for all samples processed with both the analog and digital ROQ's.

17. The weather false target rates that are experienced with the video select map are generally lower if MTI video is processed by the digital ROQ in lieu of the analog version.

RECOMMENDATIONS

It is recommended that initiative be undertaken to:

1. Utilize sampling rates of 1 to 2 MHz when employing the digital or analog ROQ's within an ASR environment.

2. Employ the digital ROQ AGC and 50/50 modifications with an eight-bit analog-to-digital converter.

3. Process normal video in place of MTI video in a clear-air environment.

4. Not employ the second-threshold control function in a clear-air environment.

5. Employ the second-threshold control function in a clutter environment.

6. Include digital ROQ's in future radar processing systems.

REFERENCE

1. Holtz, Martin H. and Wapelhorst, Leo, Test and Evaluation of the Radar Processing Subsystem of the All Digital Tracking Level System, Federal Aviation Administration Report No. FAA-RD-76-197.

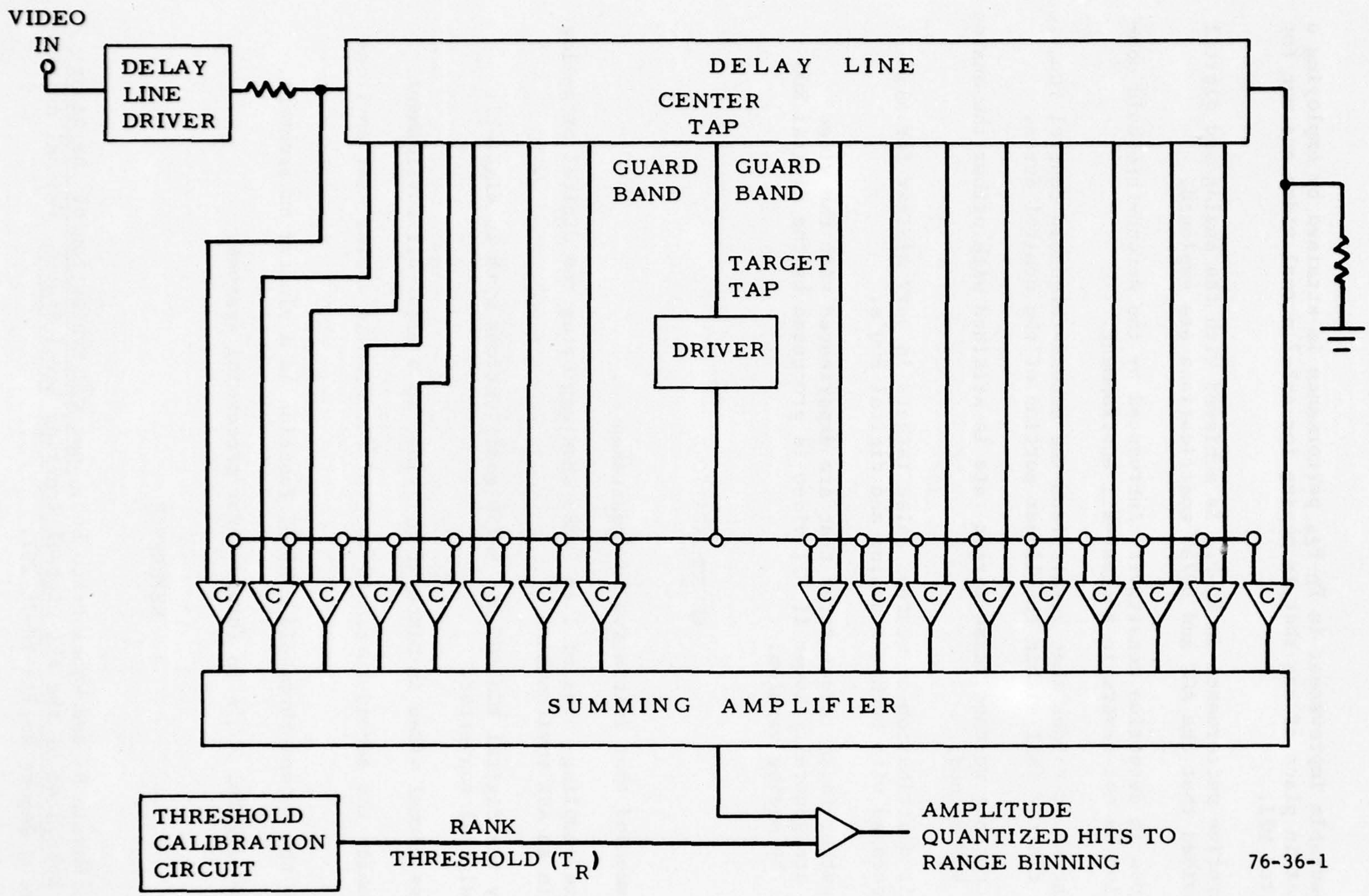


FIGURE 1. TYPICAL ANALOG RANK-ORDER QUANTIZER

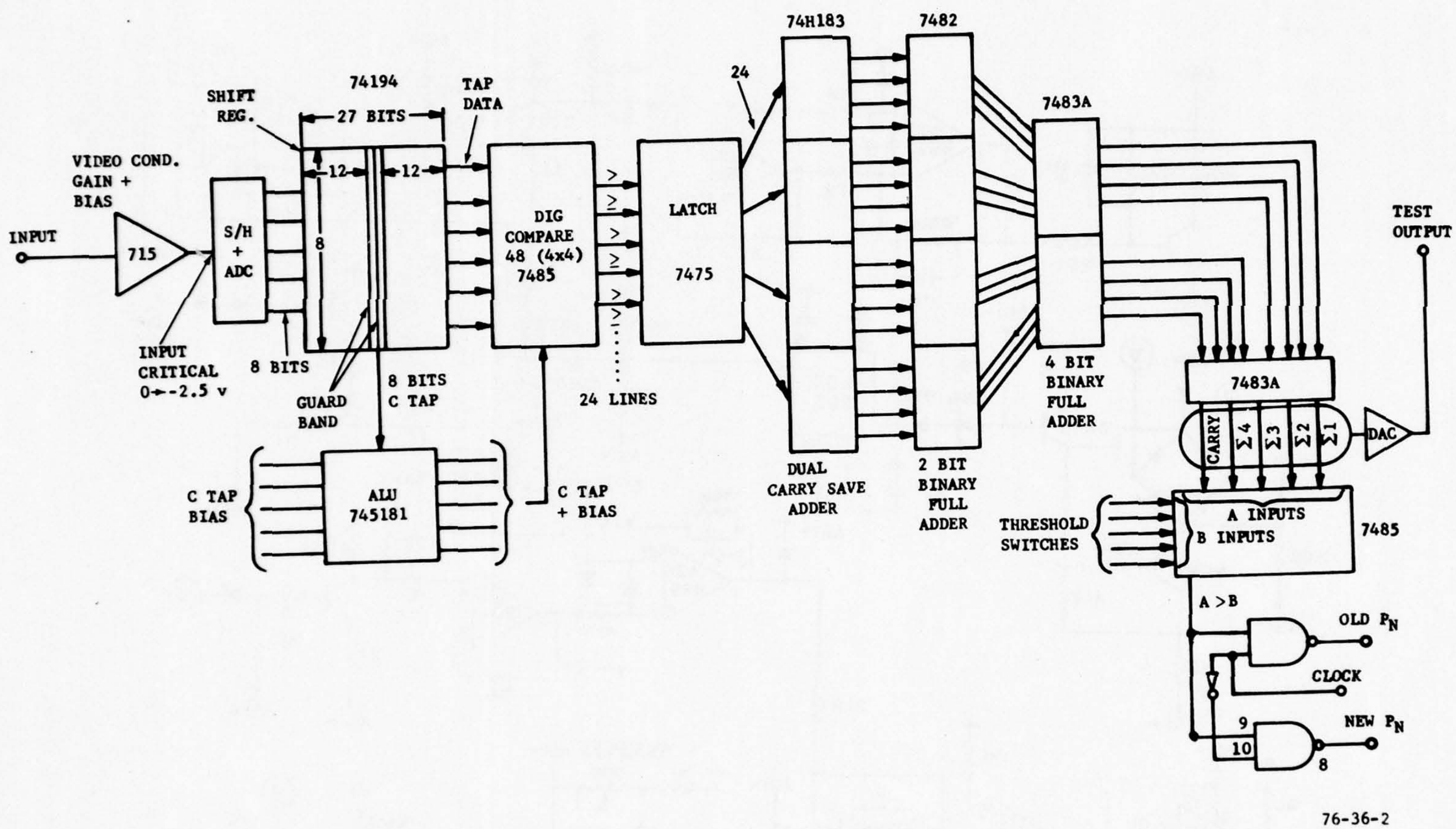


FIGURE 2. FUNCTIONAL DIAGRAM OF DIGITAL RANK-ORDER QUANTIZER

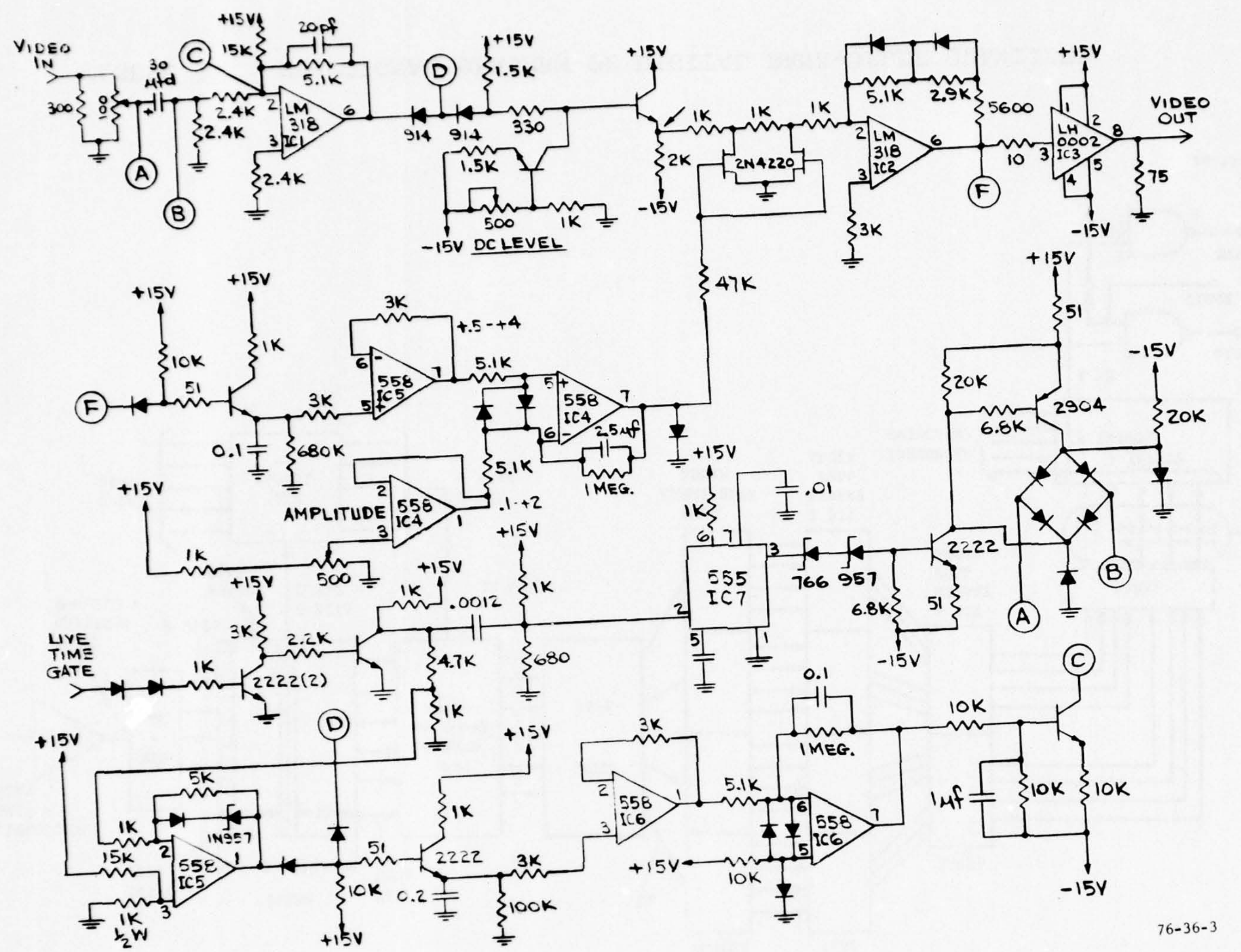


FIGURE 3. SCHEMATIC DIAGRAM FOR AGC MODIFICATION

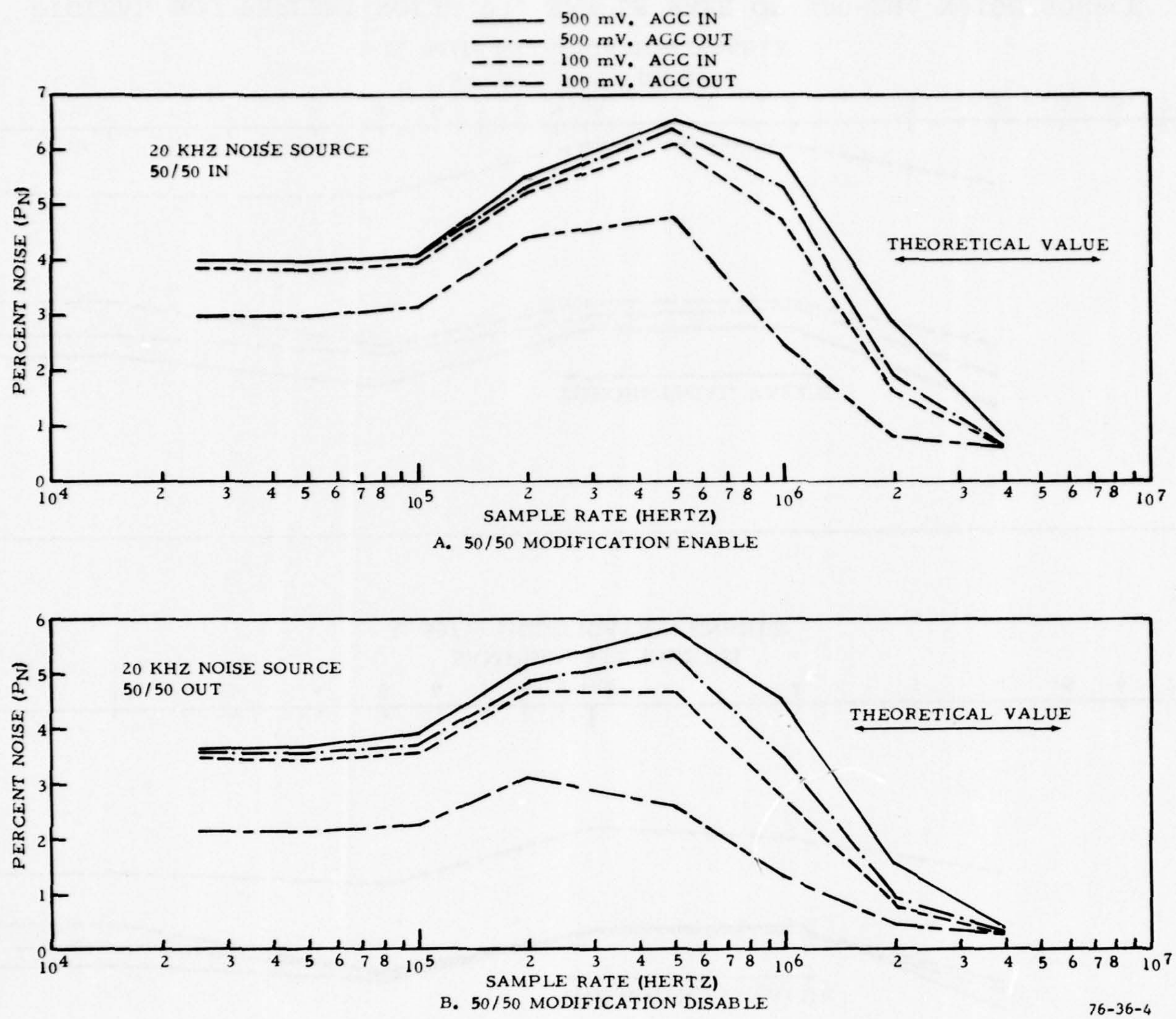


FIGURE 4. DIGITAL ROQ PERCENT NOISE VS. SAMPLE RATE FOR 20-KHZ NOISE SOURCE

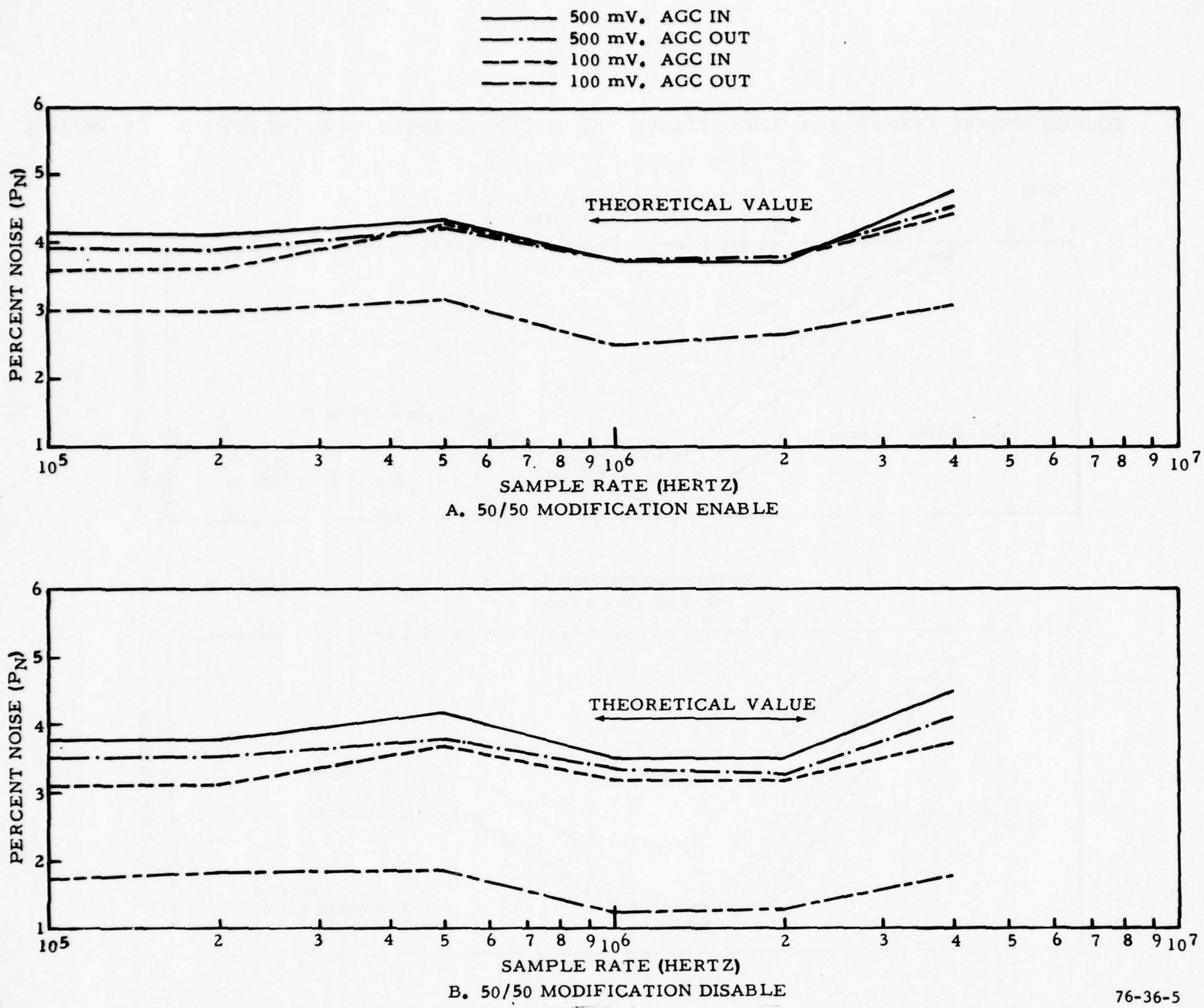


FIGURE 5. DIGITAL ROQ PERCENT NOISE VS. SAMPLE RATE OF 500-KHz NOISE SOURCE

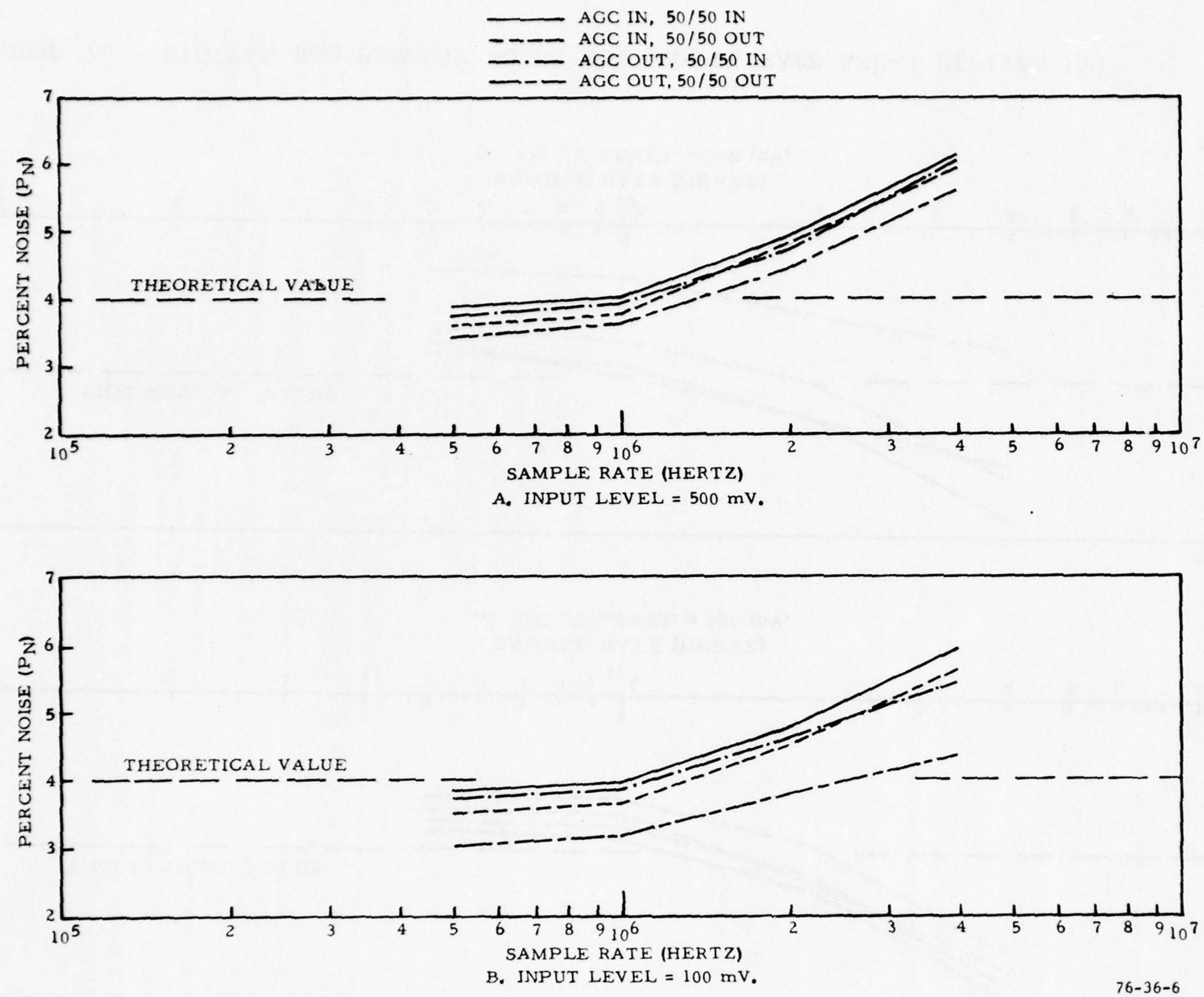


FIGURE 6. DIGITAL ROQ PERCENT NOISE VS. SAMPLE RATE ASR-5 MTI VIDEO

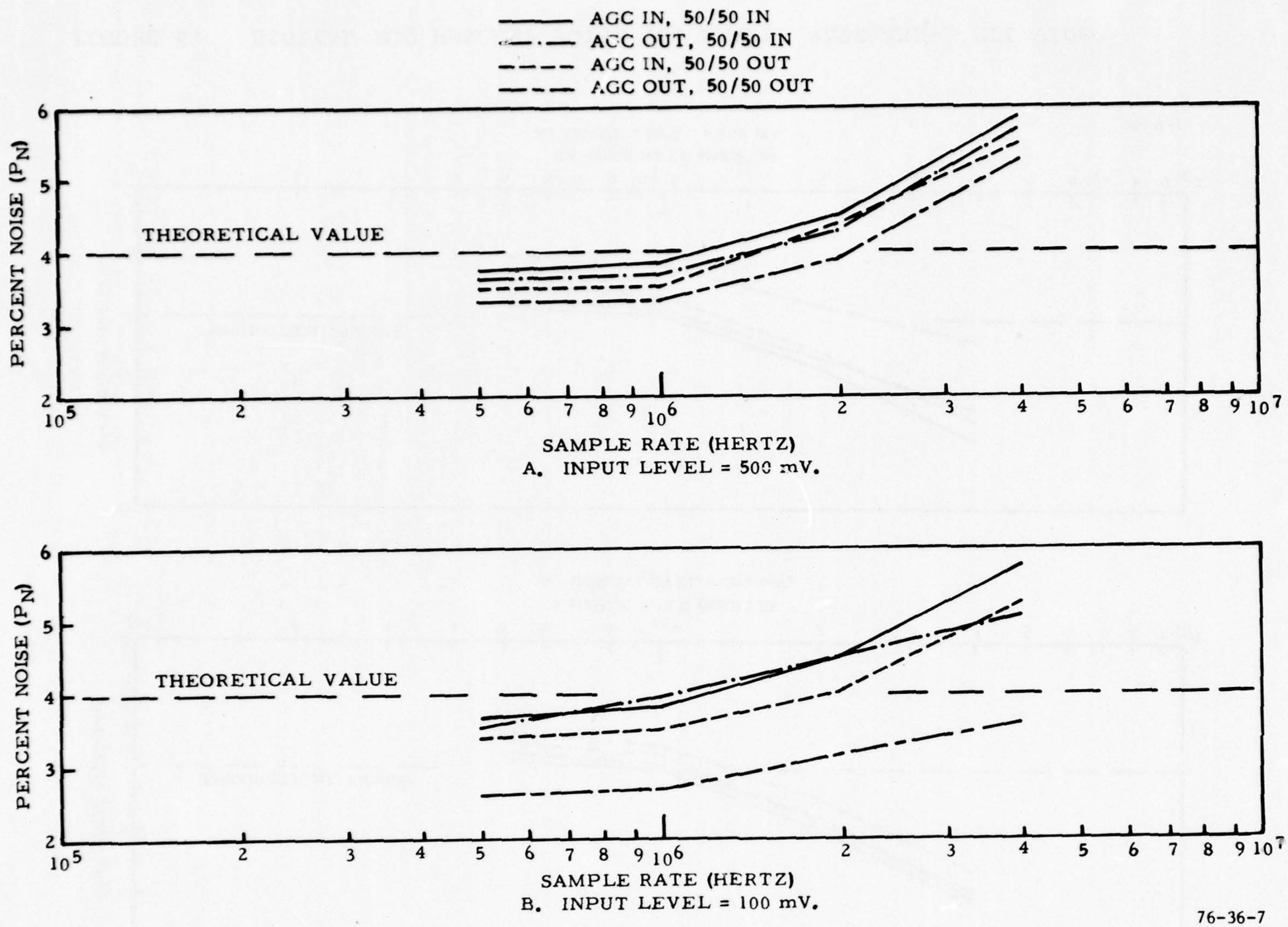


FIGURE 7. DIGITAL ROQ PERCENT NOISE VS. SAMPLE RATE ASR-7 DIGITAL MTI

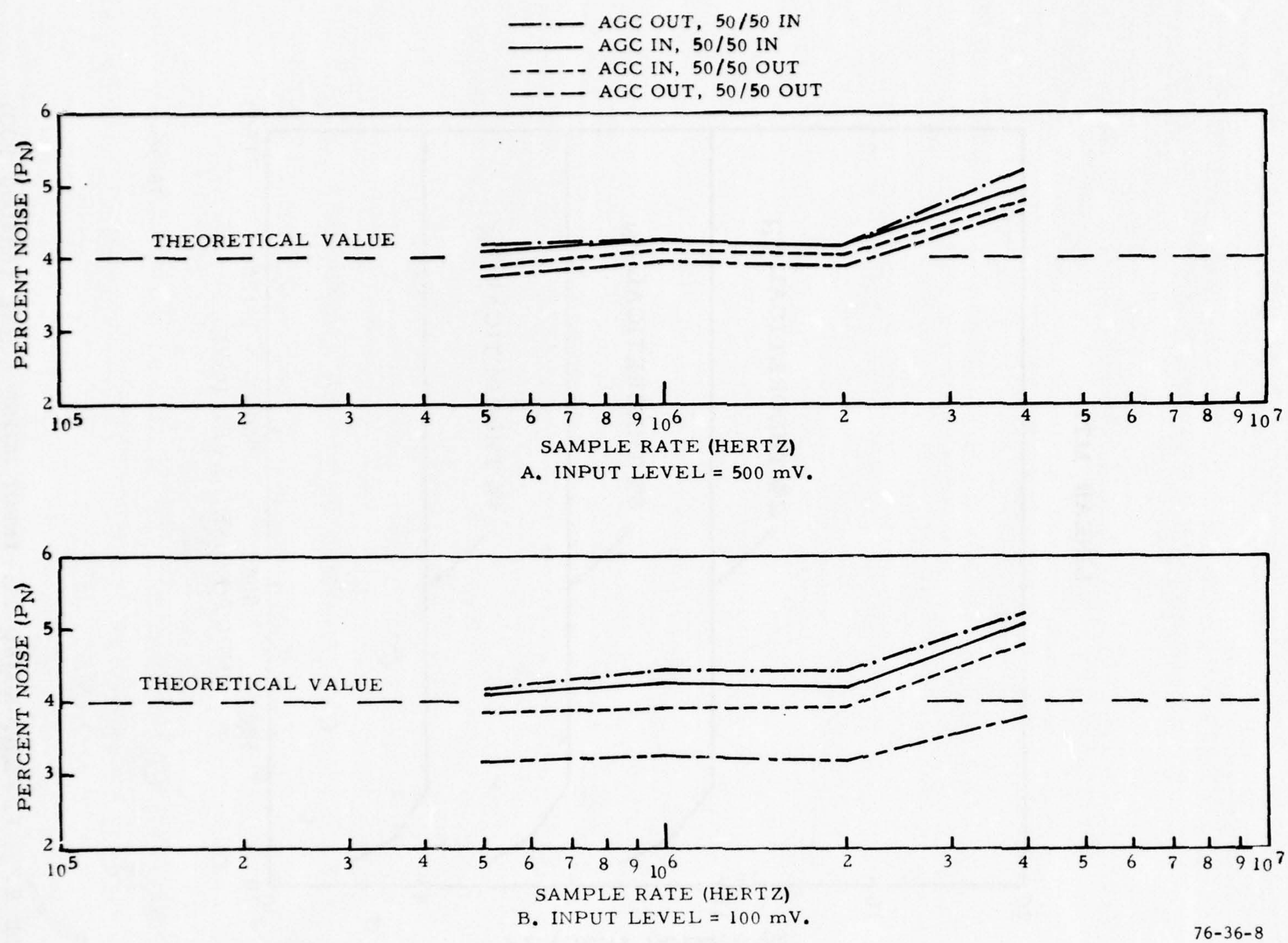


FIGURE 8. DIGITAL ROQ NOISE VS. SAMPLE RATE ASR-7 NORMAL MTI

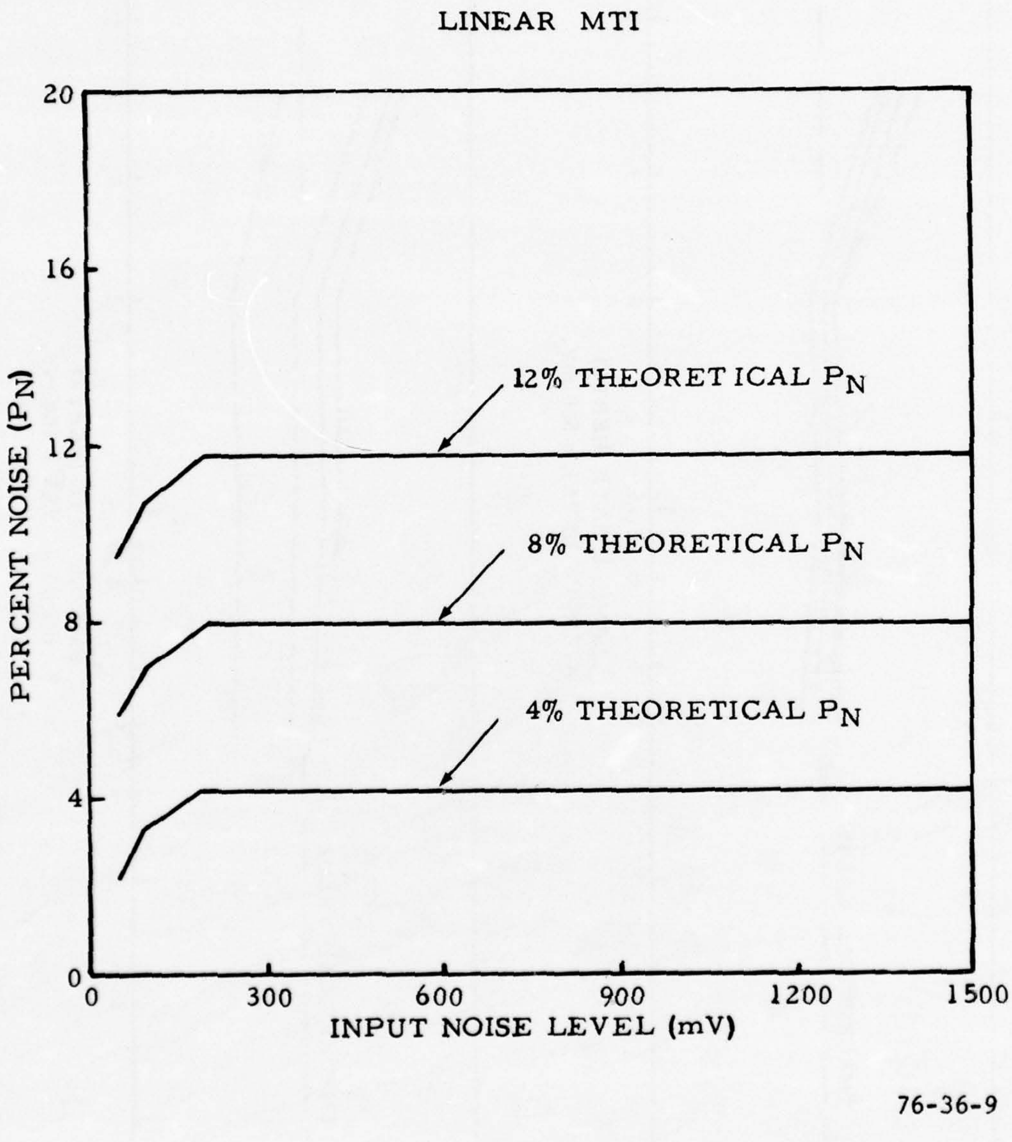
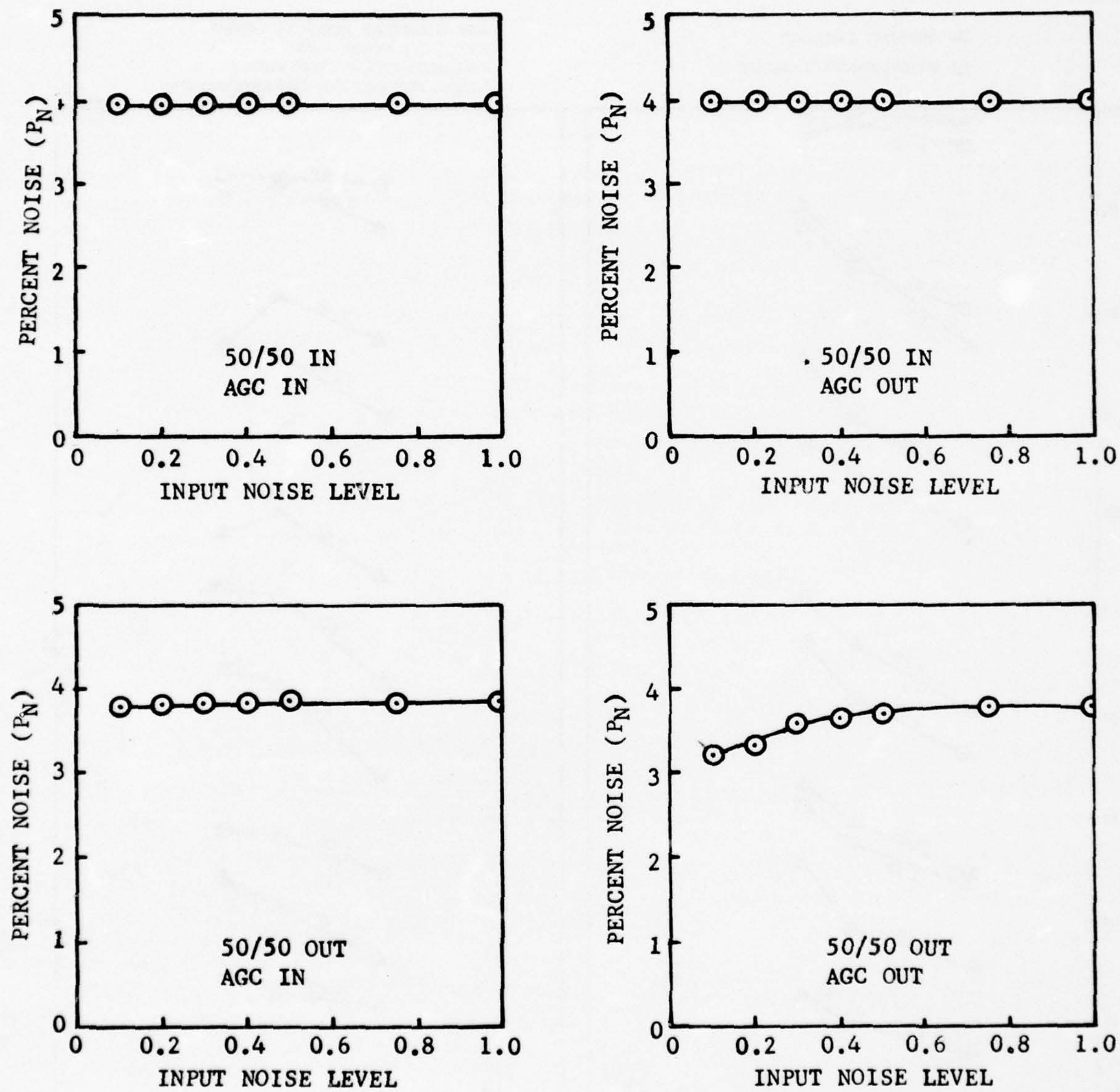


FIGURE 9. PERCENT NOISE VS. INPUT NOISE LEVEL (ANALOG ROQ)

ASR-5 LINEAR MTI



1 MHz SAMPLE RATE

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FIGURE 10. PERCENT NOISE VS. INPUT NOISE LEVEL (DIGITAL ROQ)

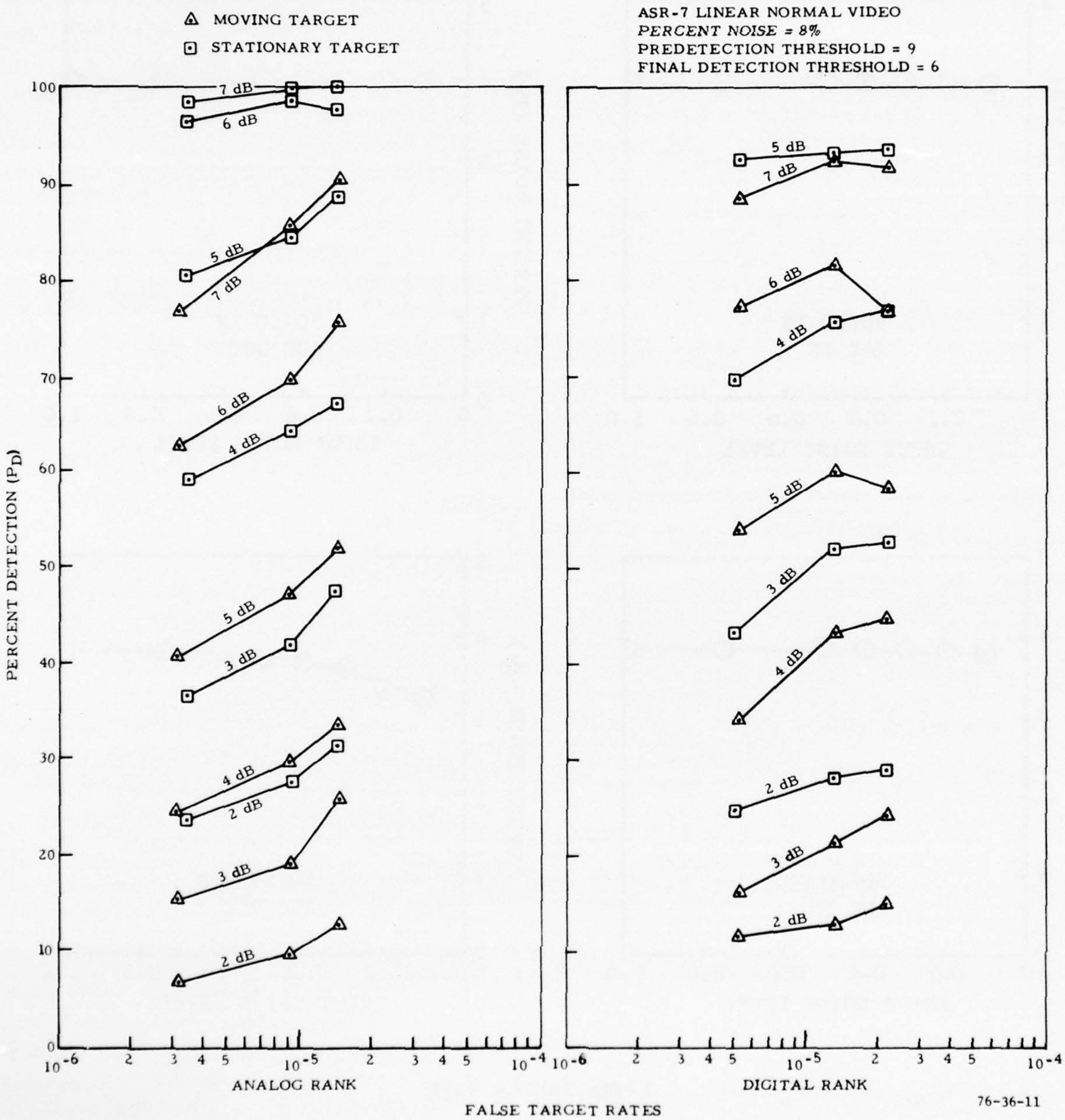

FIGURE 11. PERCENT DETECTION VS. FALSE TARGET RATES FOR MOVING TARGETS VS. STATIONARY TARGETS (ASR-7 LINEAR NORMAL)

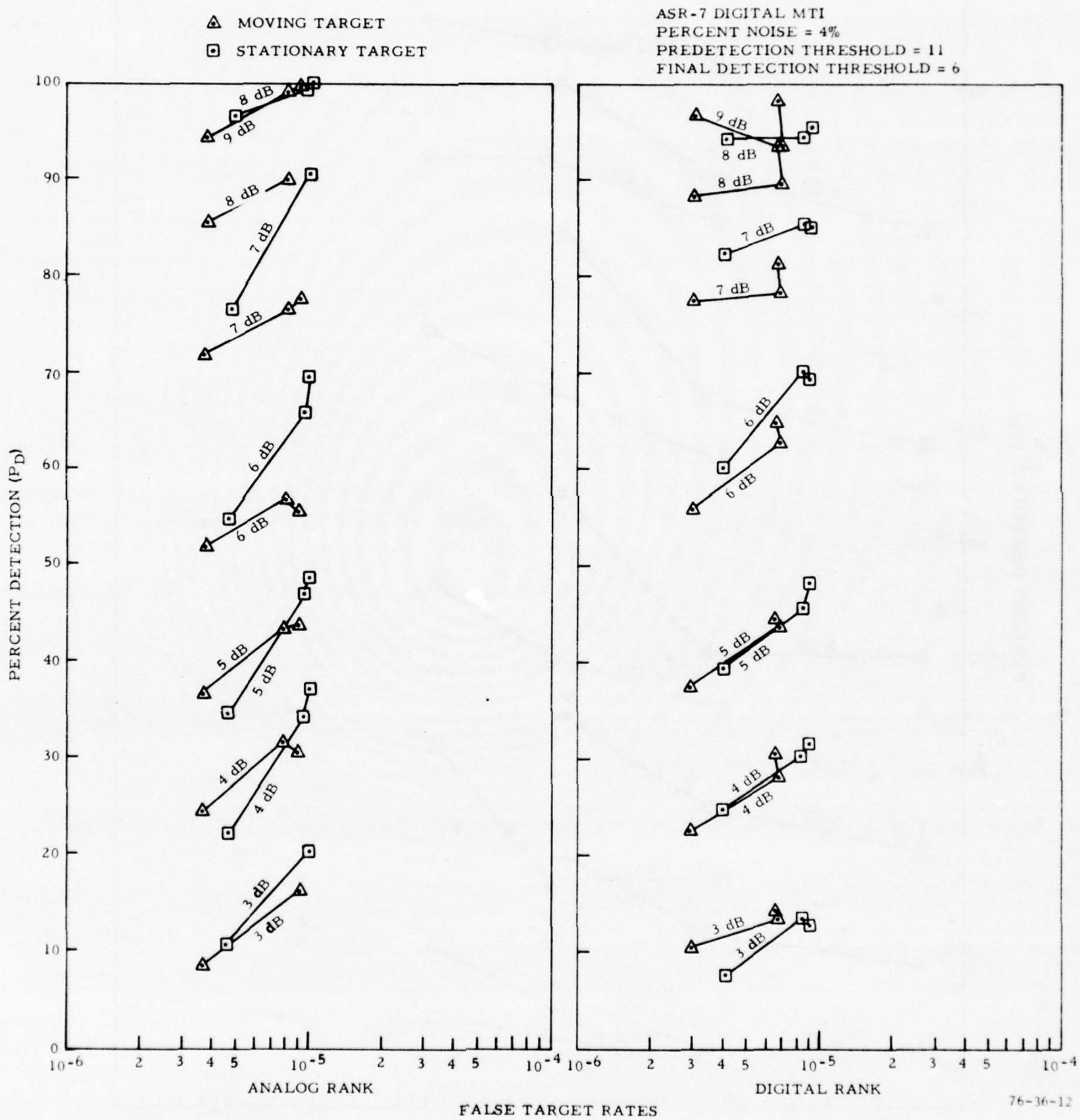

FIGURE 12. PERCENT DETECTION VS. FALSE TARGET RATES FOR MOVING TARGETS VS. STATIONARY TARGETS (ASR-7 DIGITAL MTI)

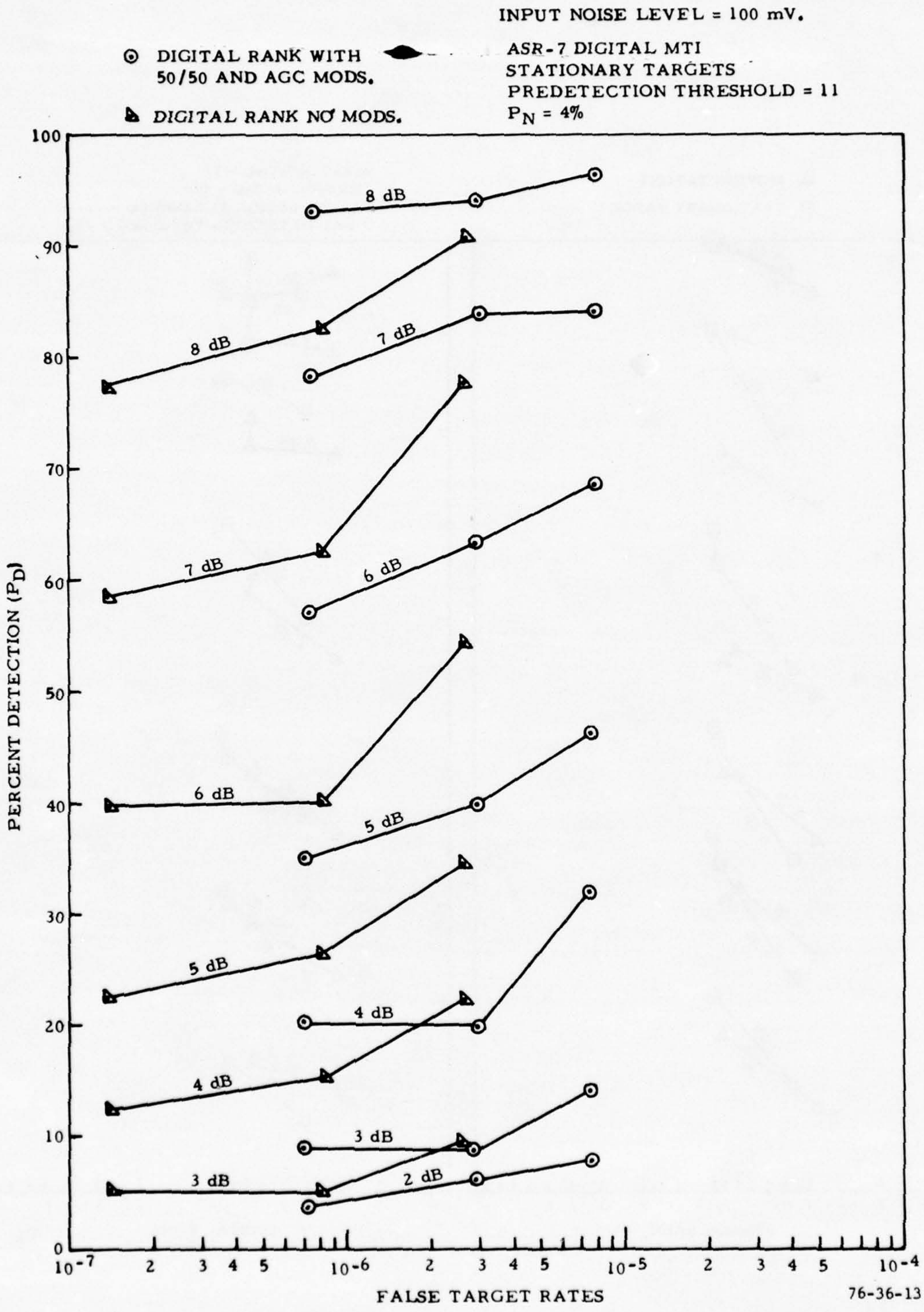

FIGURE 13. PERCENT DETECTION VS. FALSE TARGET RATES (DIGITAL ROQ WITH AND WITHOUT MODIFICATIONS)

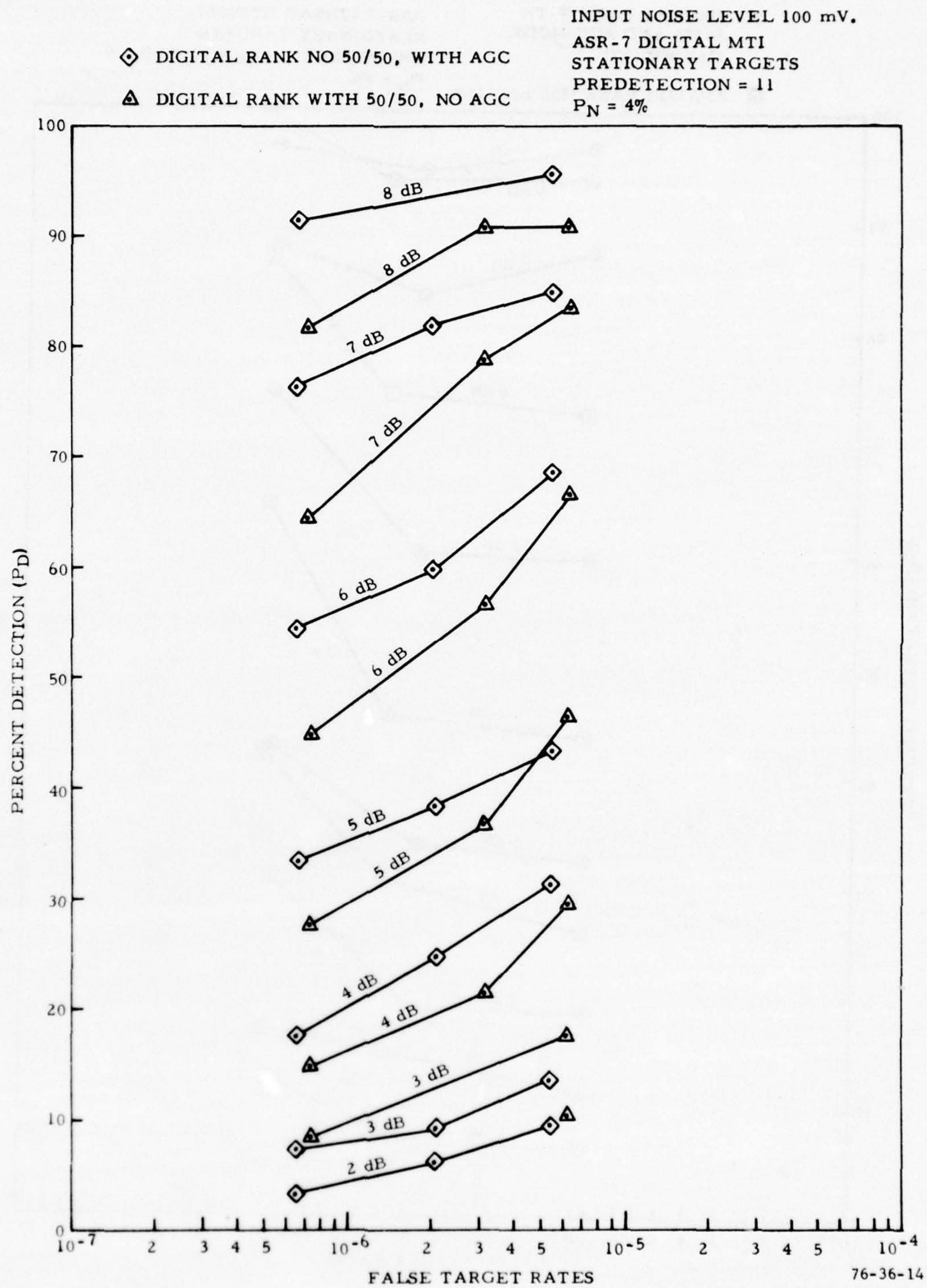

FIGURE 14. PERCENT DETECTION VS. FALSE TARGET RATES (DIGITAL ROQ WITHOUT 50/50 AND WITH AGC VS. 50/50 ENABLED WITH NO AGC

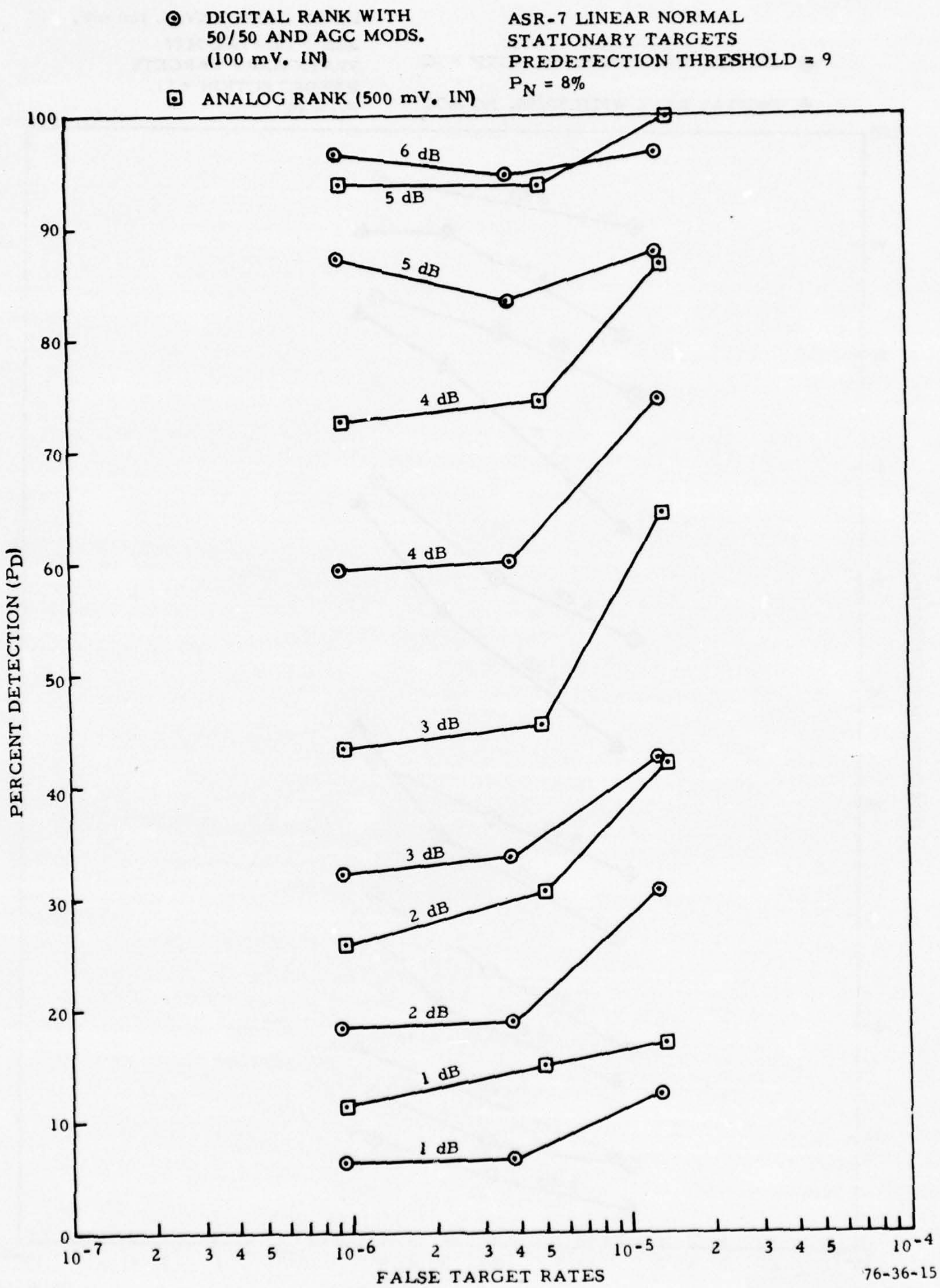

FIGURE 15. PERCENT DETECTION VS. FALSE TARGET RATES (DIGITAL ROQ WITH MODIFICATIONS VS. ANALOG ROQ)

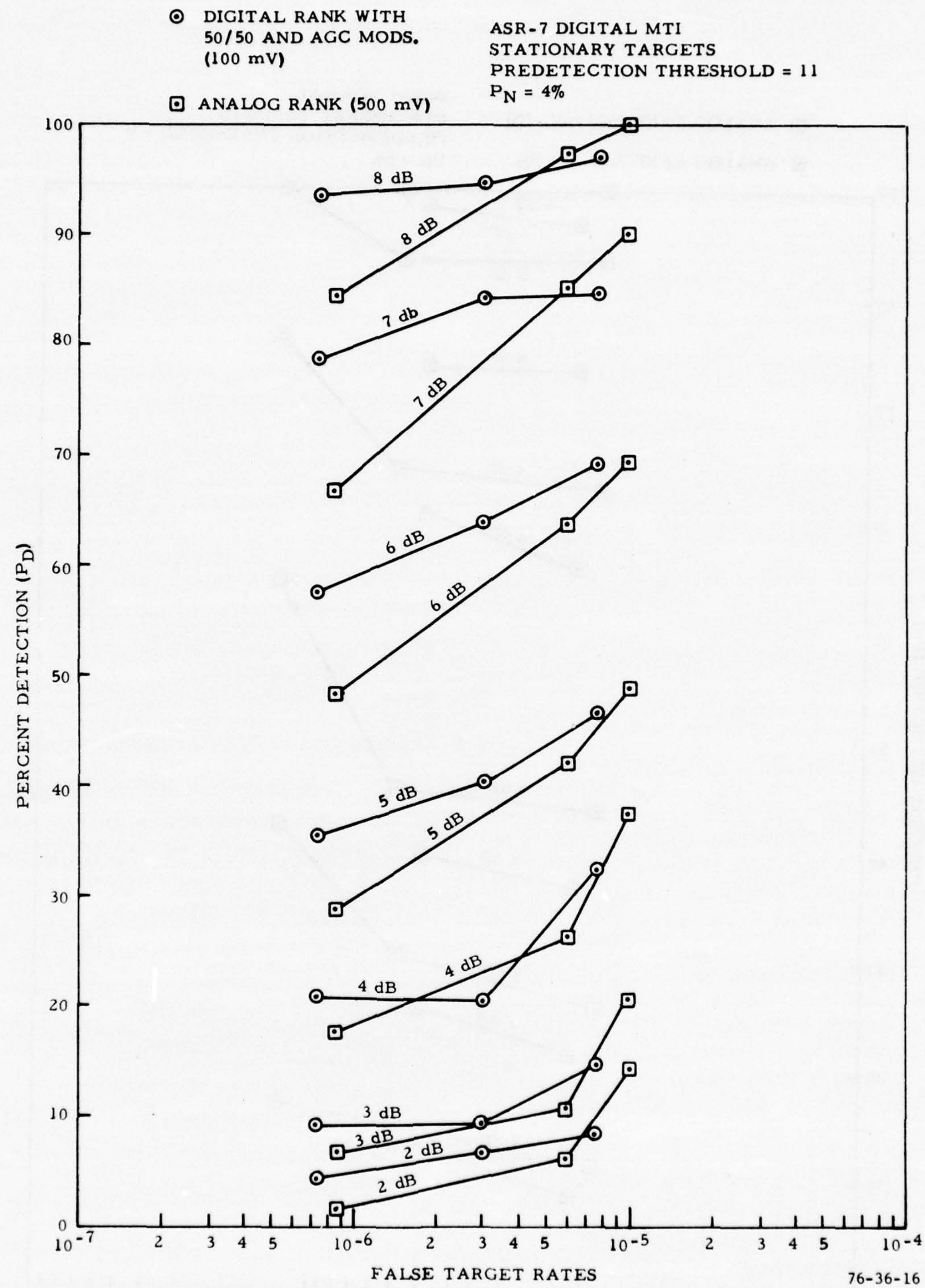

FIGURE 16. PERCENT DETECTION VS. FALSE TARGET RATES (DIGITAL ROQ WITH MODIFICATIONS VS. ANALOG ROQ)

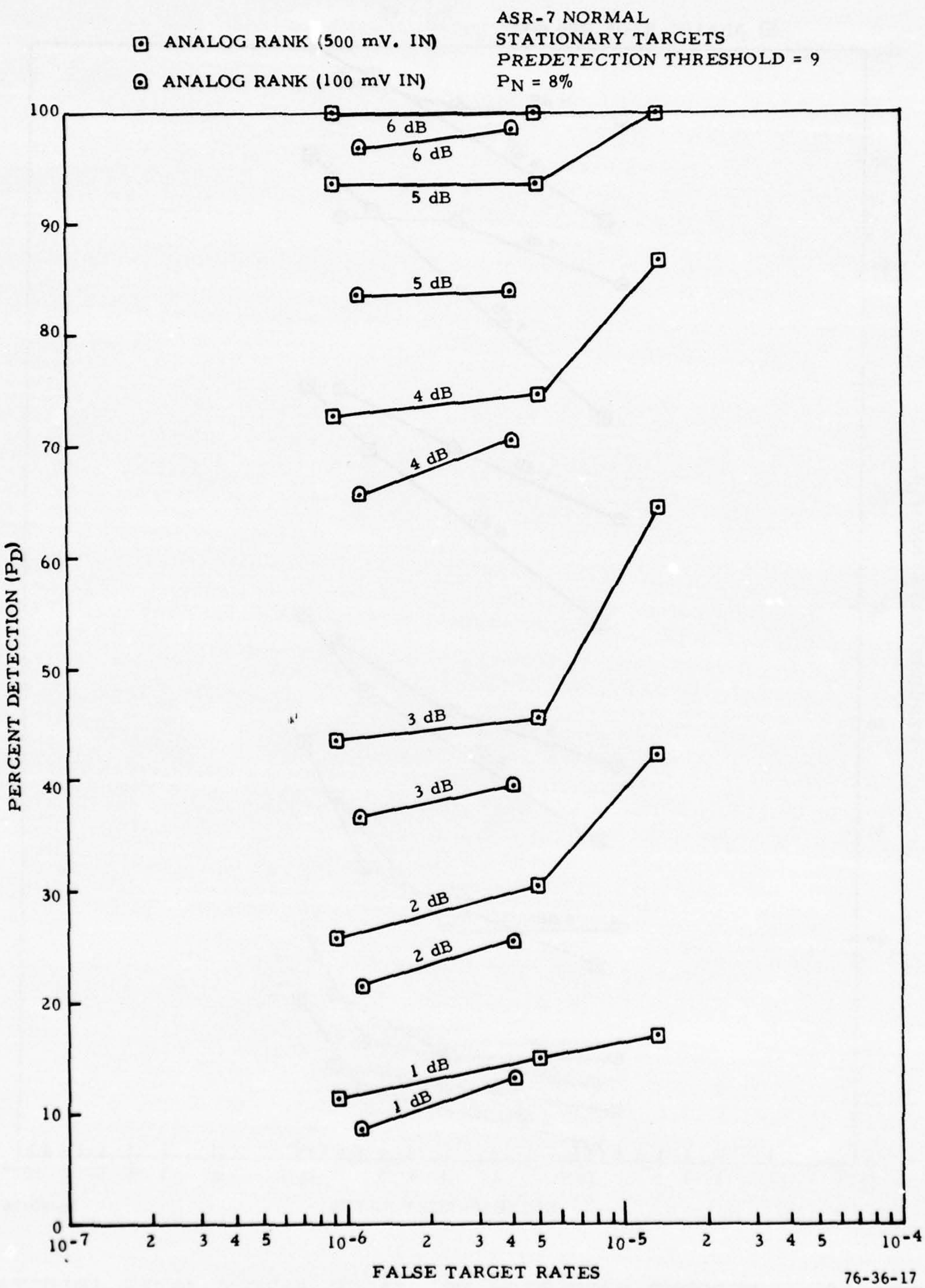

FIGURE 17. PERCENT DETECTION VS. FALSE TARGET RATES (ANALOG ROQ 100 AND 500 mV/N)

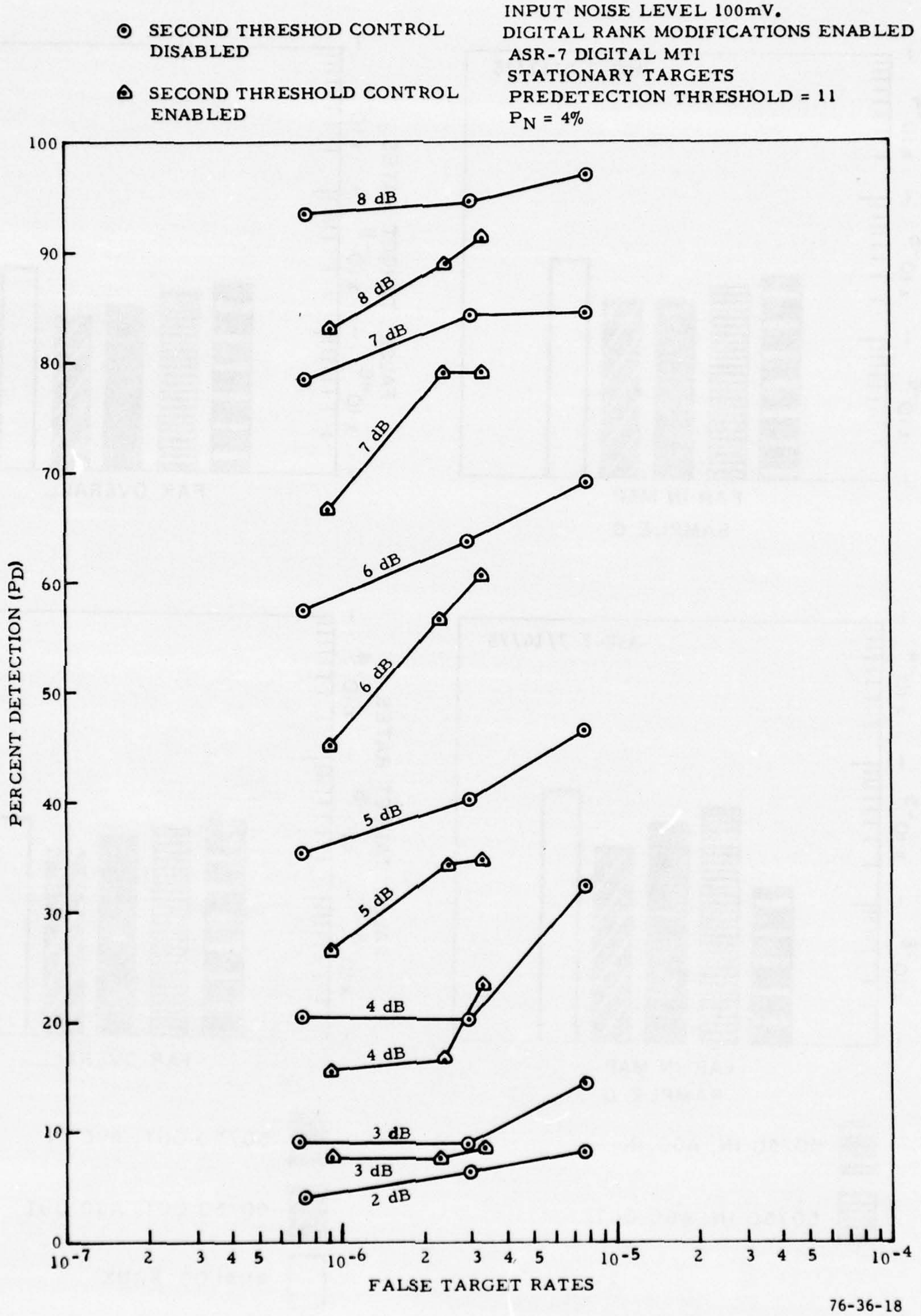

FIGURE 18. PERCENT DETECTION VS. FALSE TARGET RATES (DIGITAL ROQ WITH MODIFICATIONS OR THRESHOLD CONTROL ENABLE AND DISABLED)

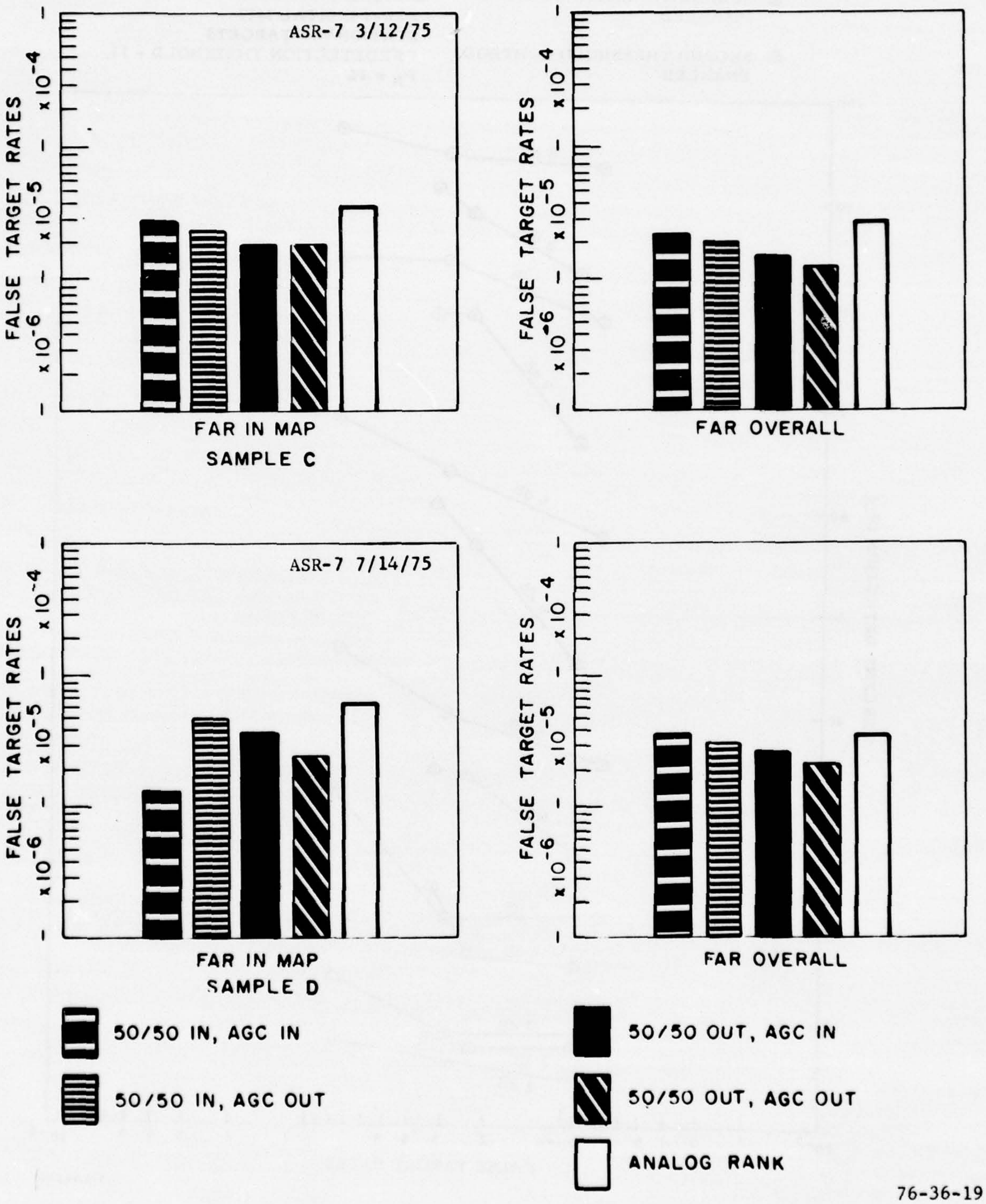

FIGURE 19. WEATHER FALSE TARGET RATES

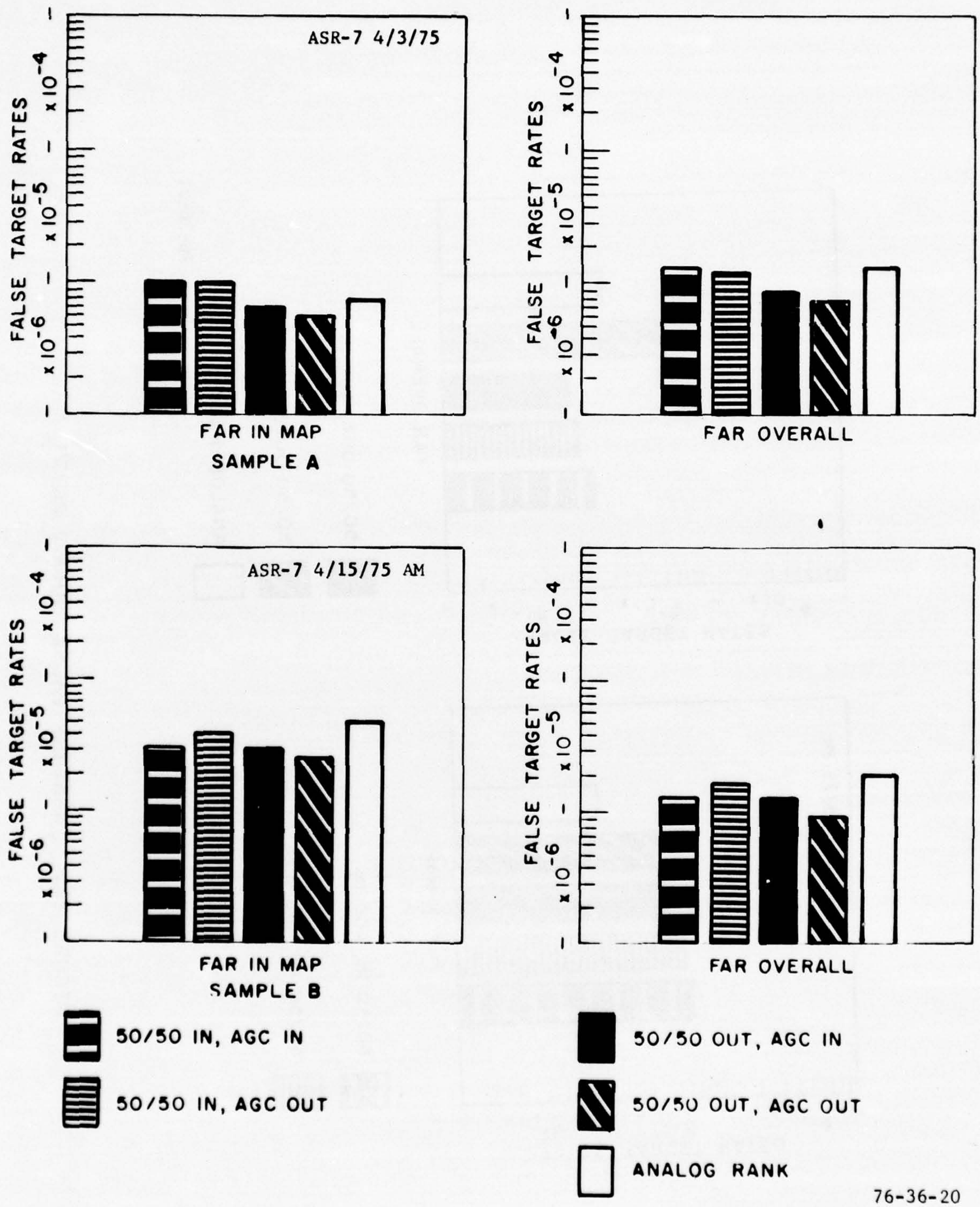

FIGURE 20. WEATHER FALSE TARGET RATES

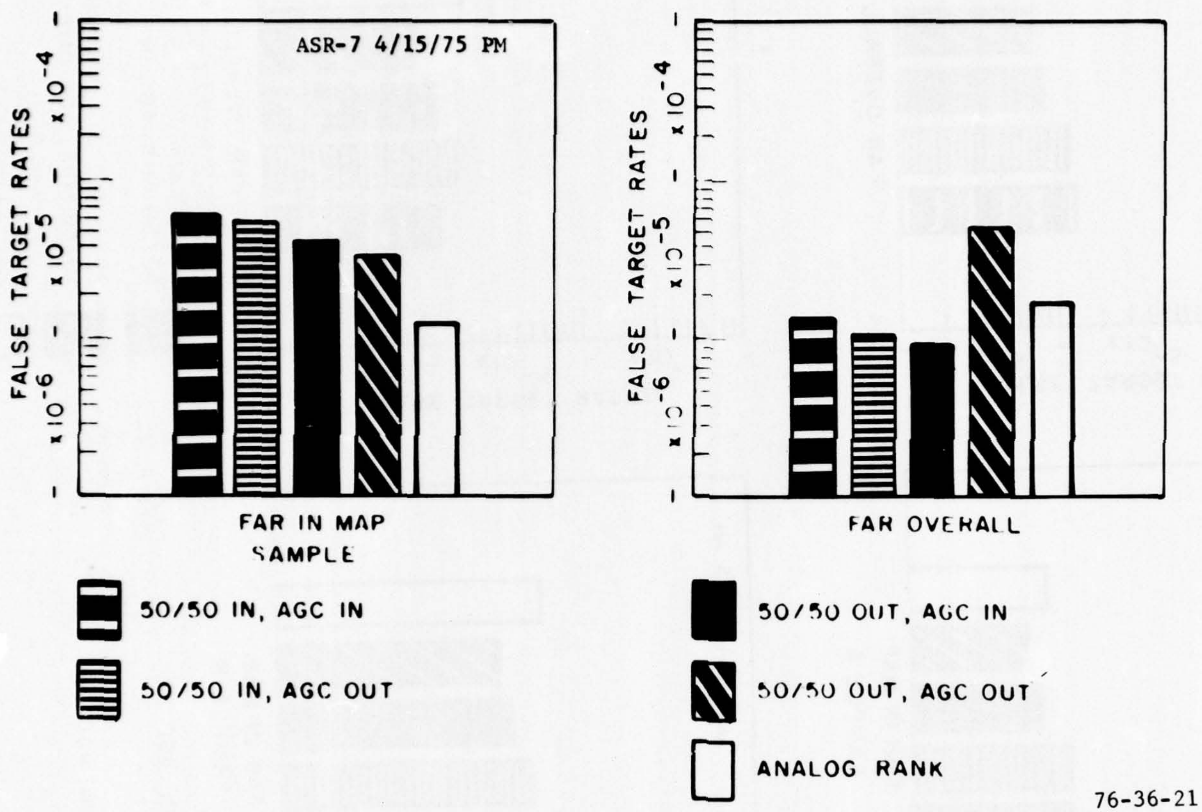

FIGURE 21. WEATHER FALSE TARGET RATES

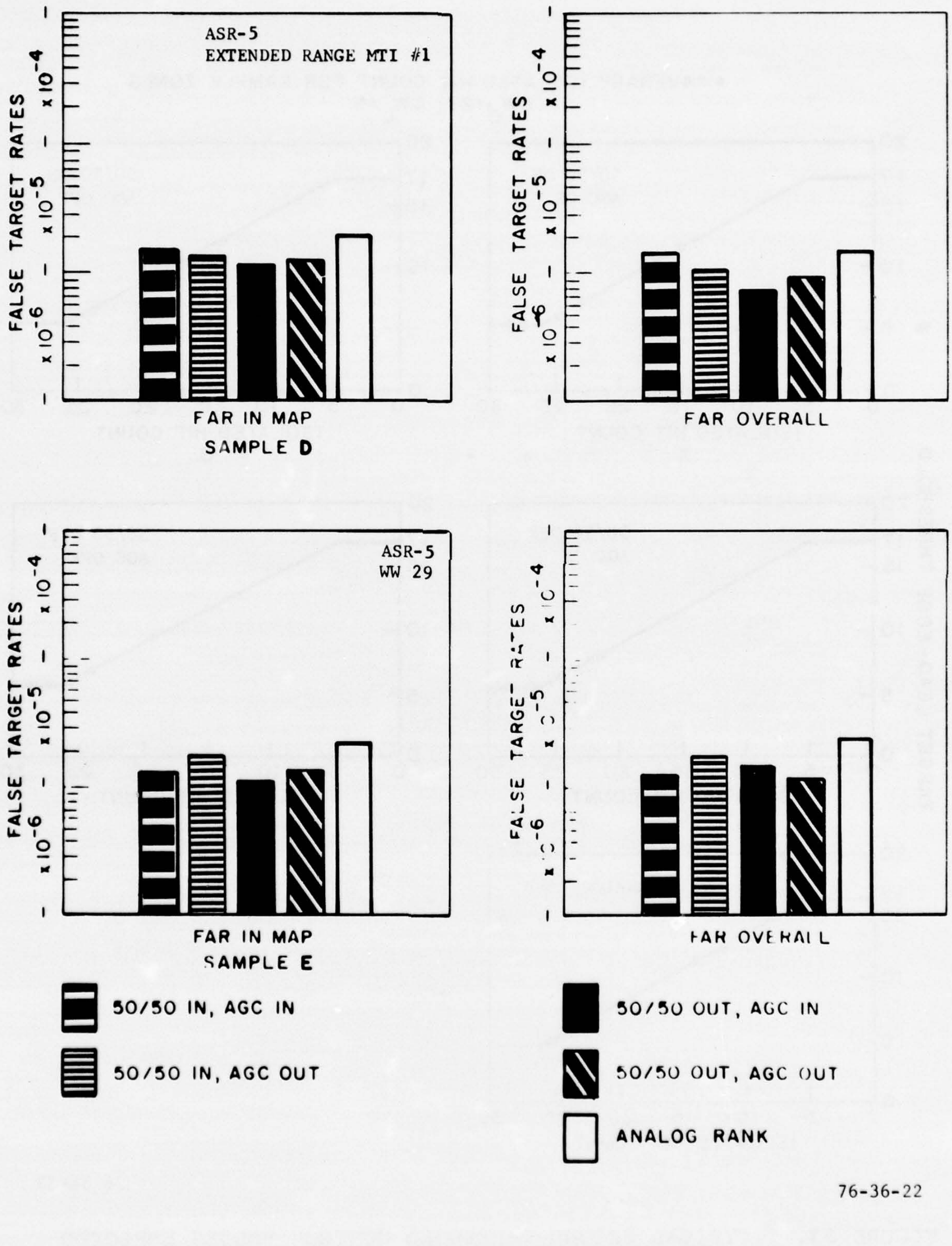

FIGURE 22. WEATHER FALSE TARGET RATES

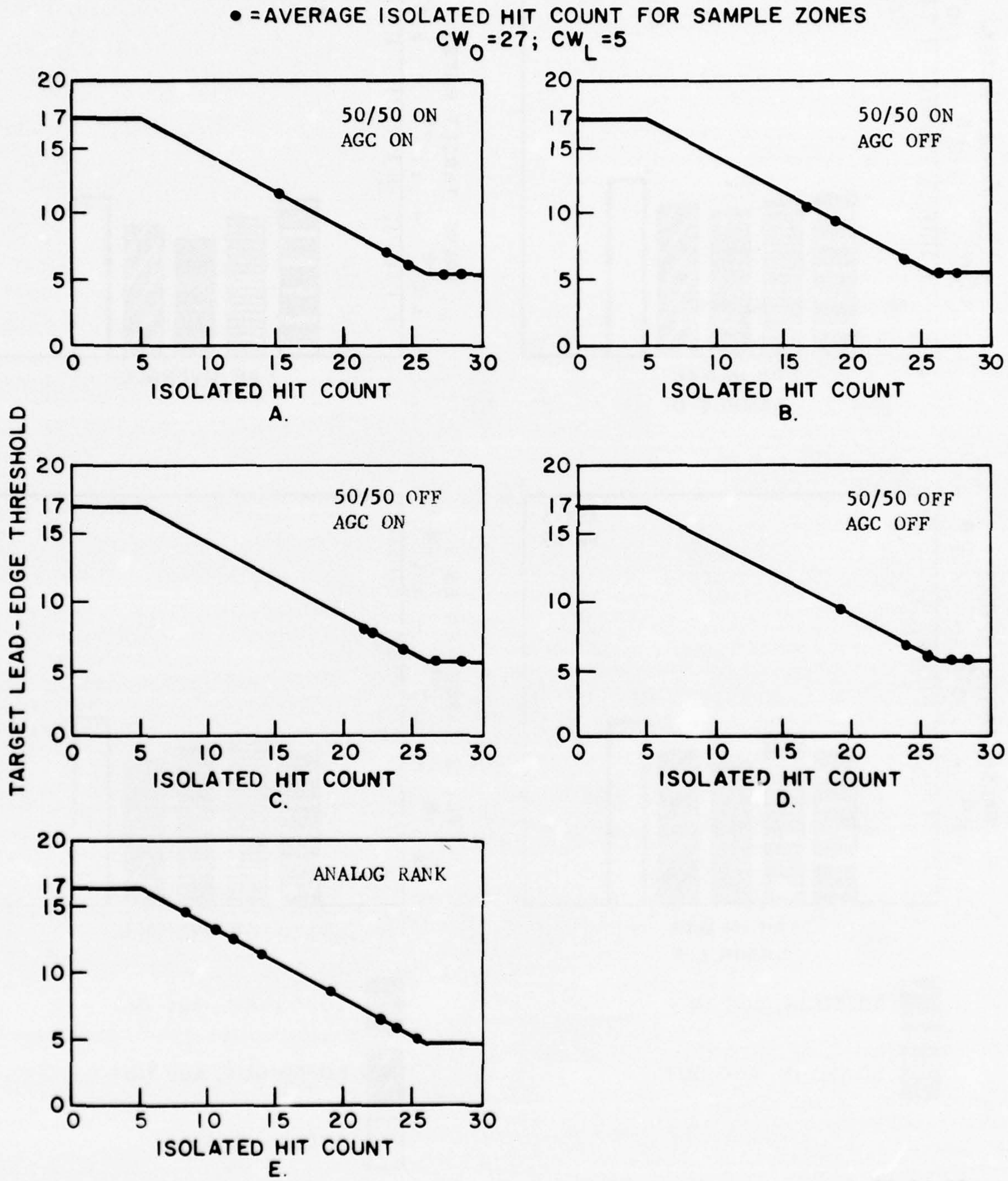

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FIGURE 23. TYPICAL SECOND-THRESHOLD CONTROL VALUES EMPLOYED FOR ASR-7, 3/12/75

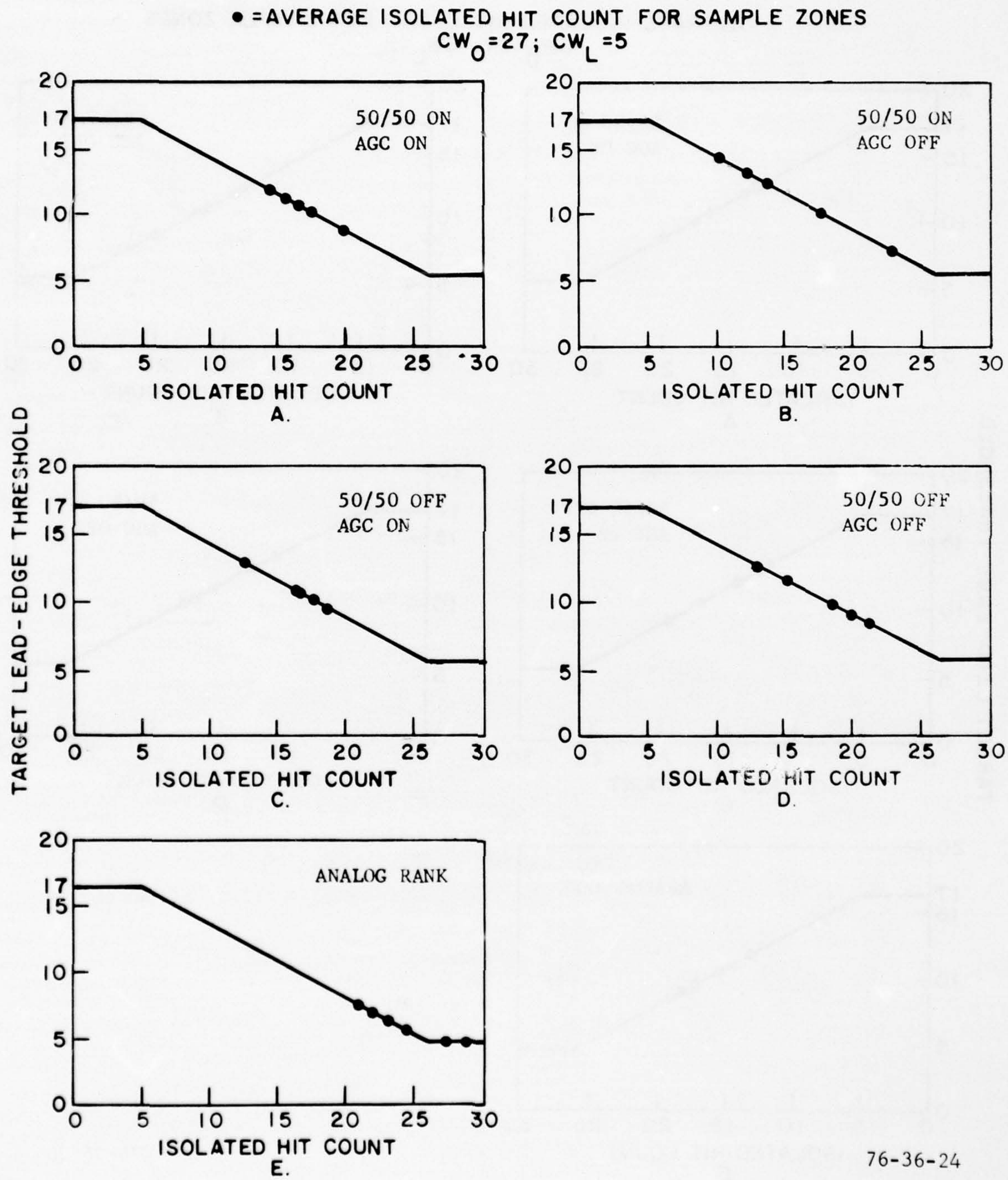

FIGURE 24. TYPICAL SECOND-THRESHOLD CONTROL VALUES EMPLOYED FOR ASR-7, 7/14/75

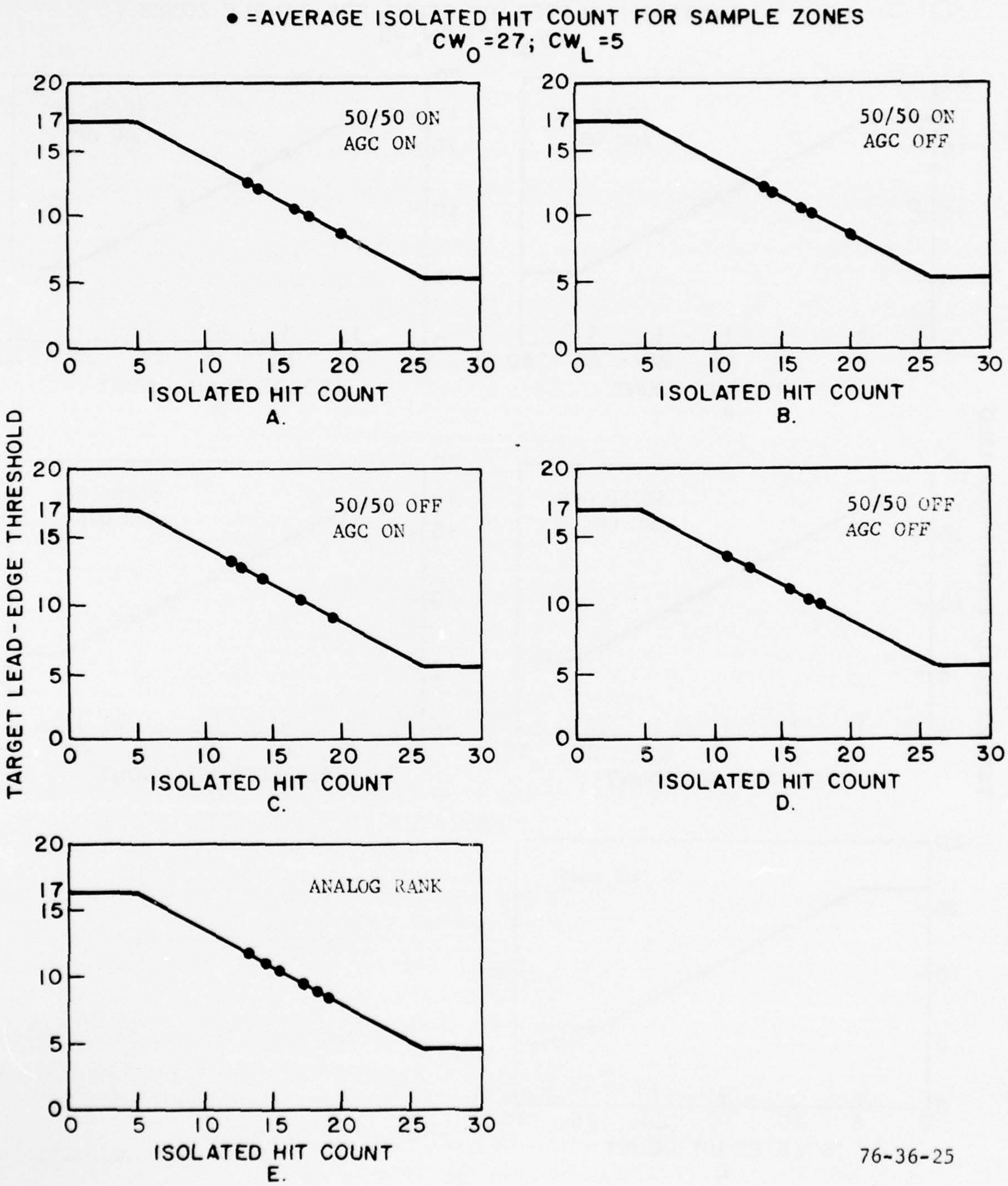

FIGURE 25. TYPICAL SECOND-THRESHOLD CONTROL VALUES EMPLOYED FOR ASR-5

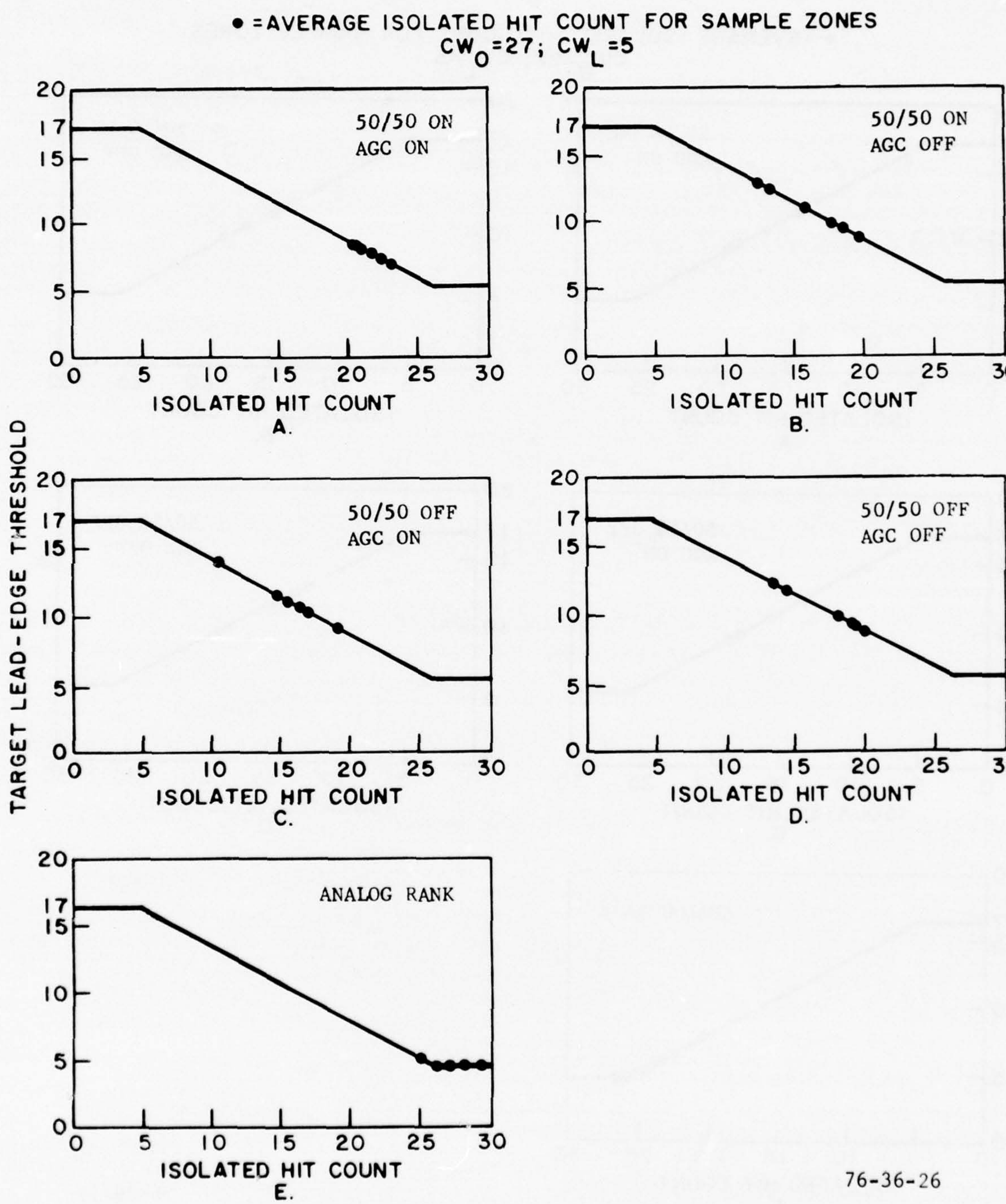

FIGURE 26. TYPICAL SECOND-THRESHOLD CONTROL VALUES EMPLOYED FOR ASR-7, 4/15/75 P.M.

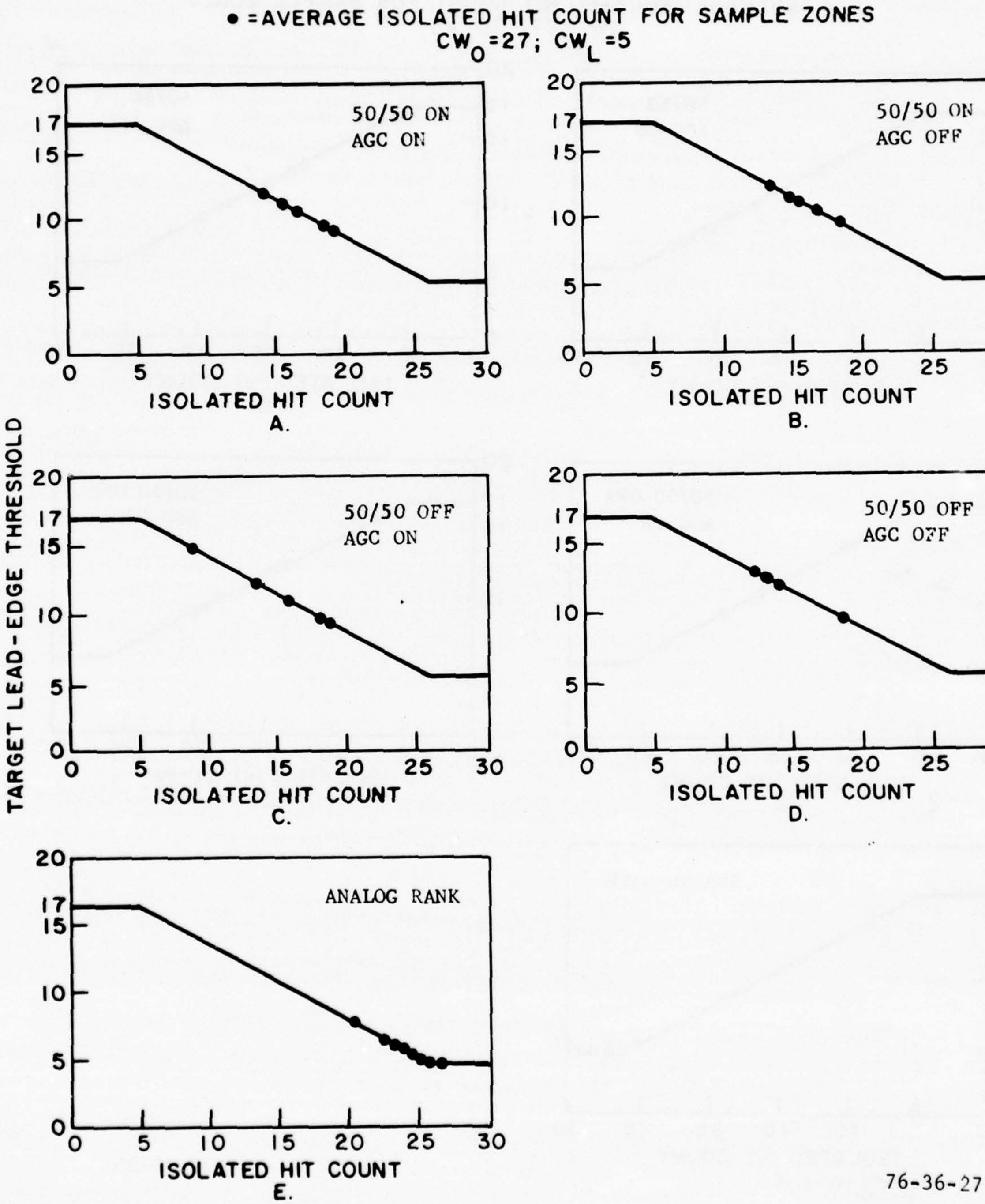

FIGURE 27. TYPICAL SECOND-THRESHOLD CONTROL VALUES EMPLOYED FOR ASR-7, 4/15/75 A.M.

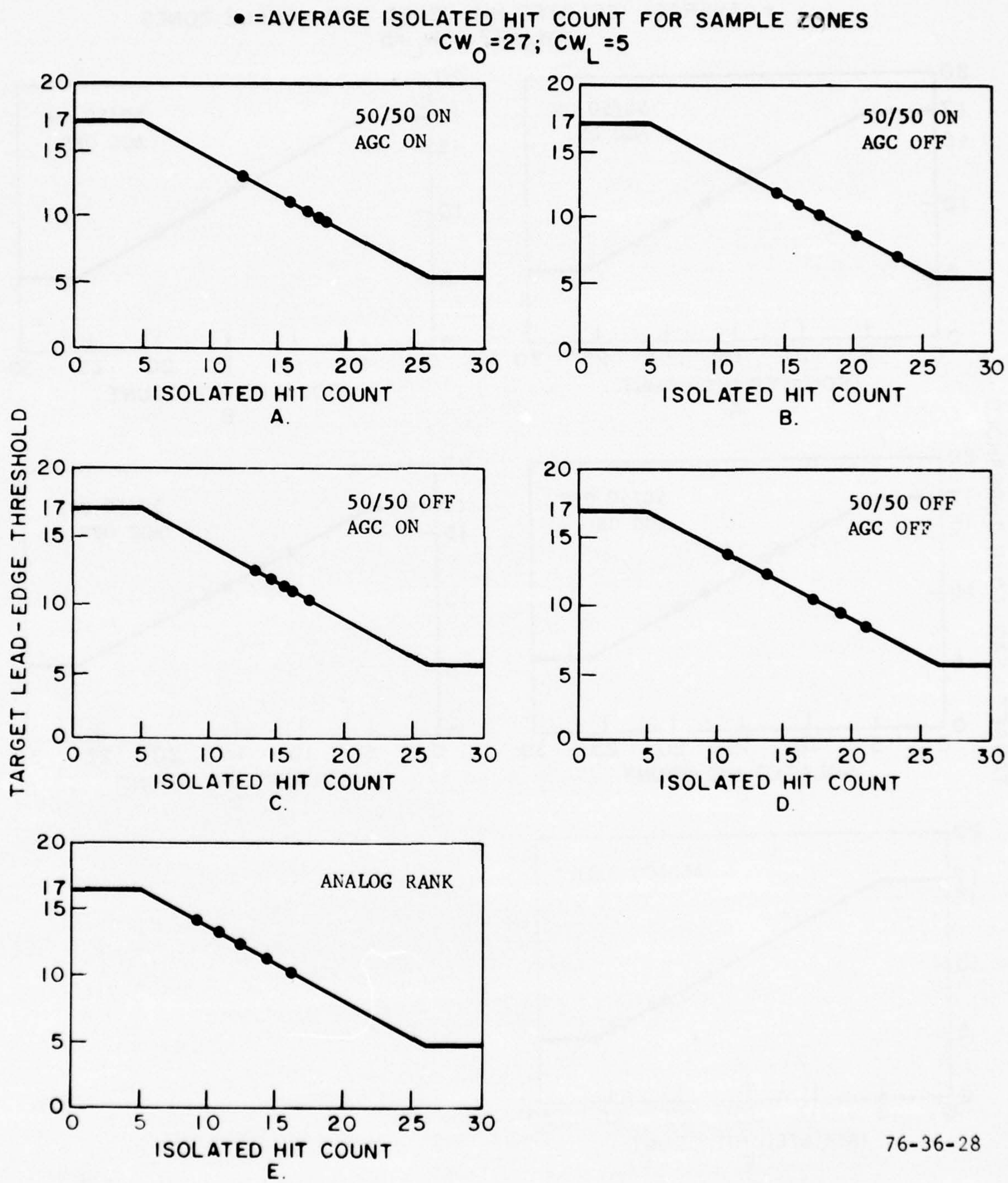

FIGURE 28. TYPICAL SECOND-THRESHOLD CONTROL VALUES EMPLOYED FOR ASR-7, 4/3/75

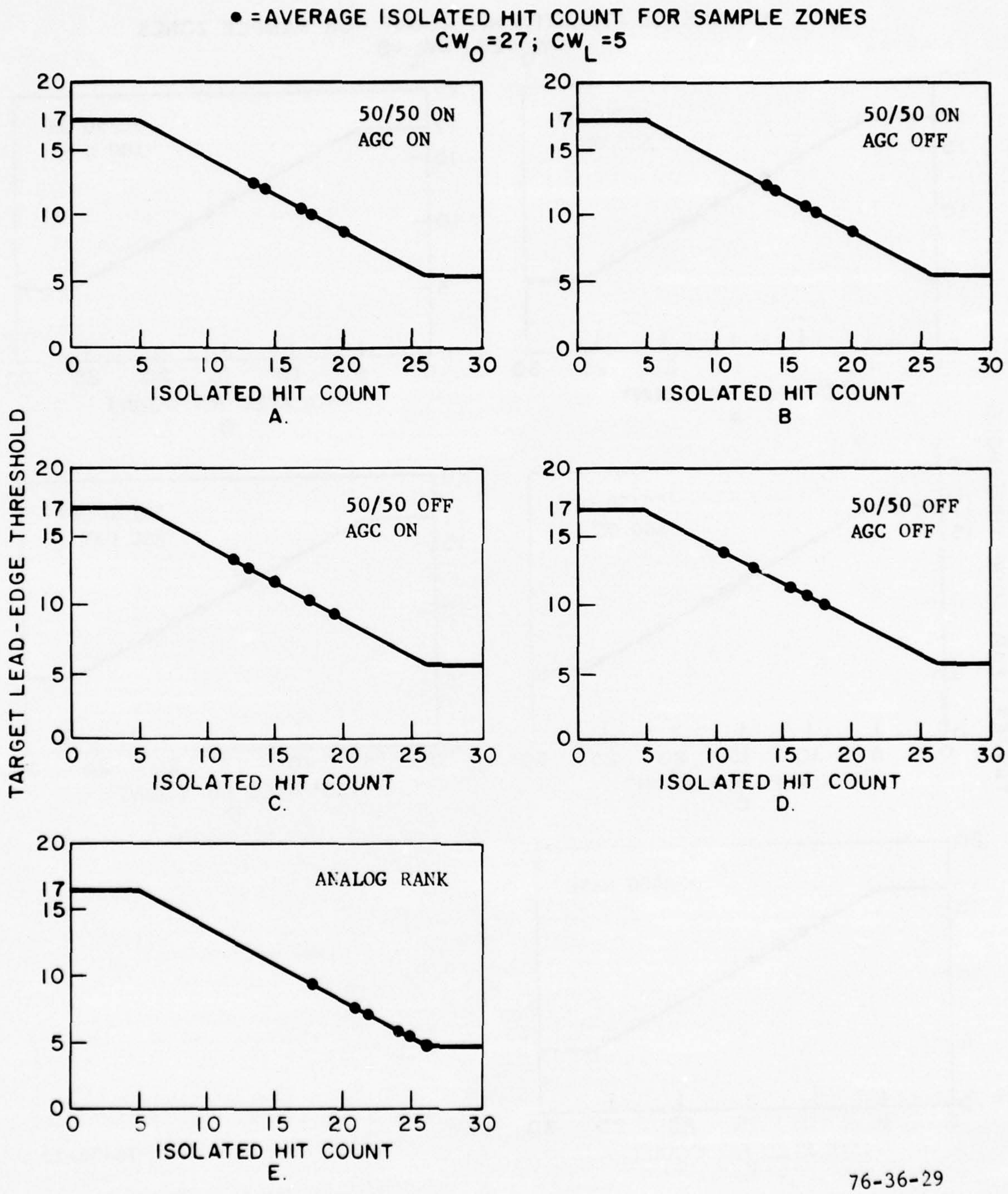

FIGURE 29. TYPICAL SECOND-THRESHOLD CONTROL VALUES EMPLOYED FOR ASR-5 EXTENDED RANGE MTI NO. 1

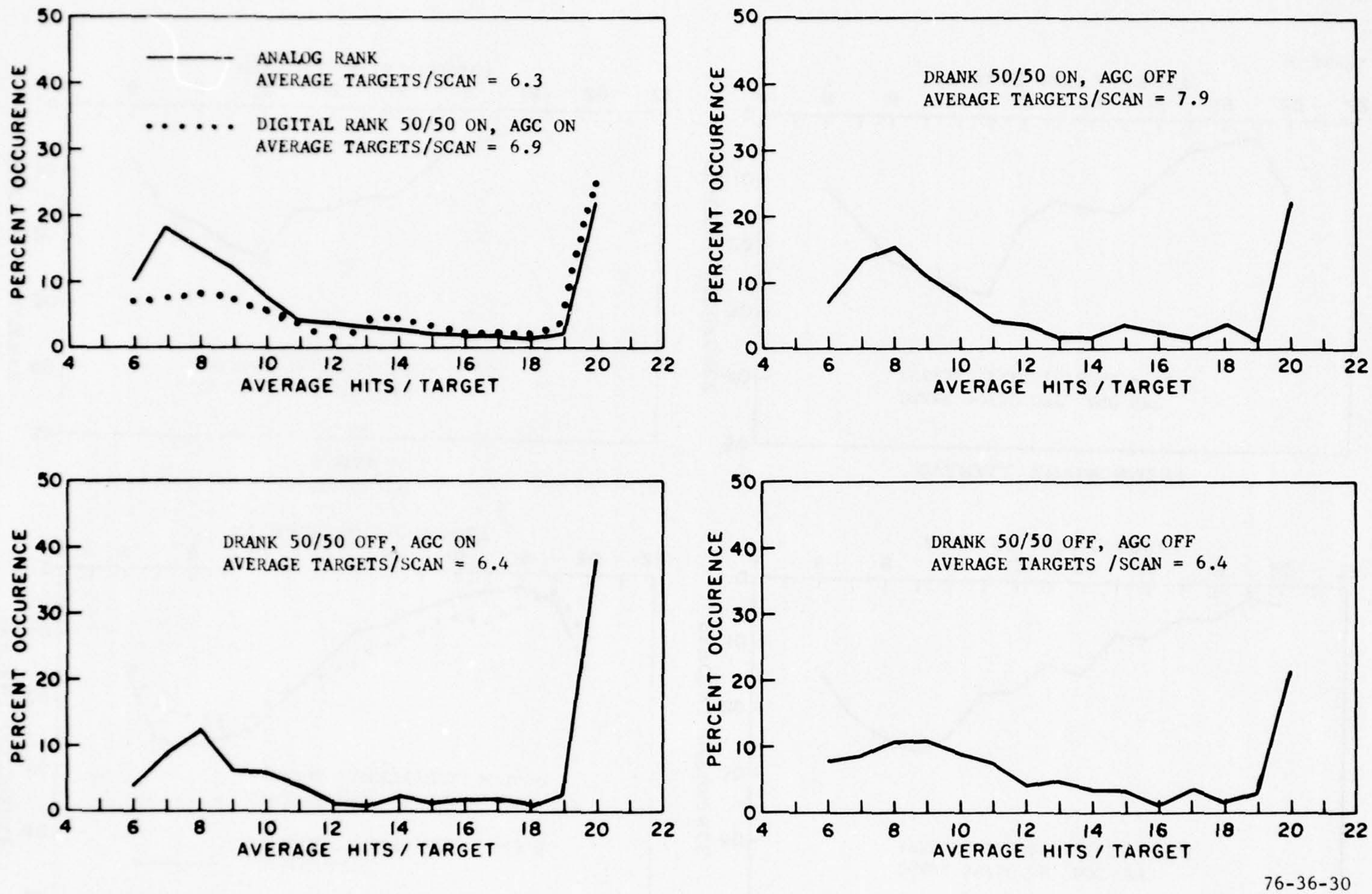

FIGURE 30. TARGET HIT DISTRIBUTION, ASR-5 MTI, TAPE WW29

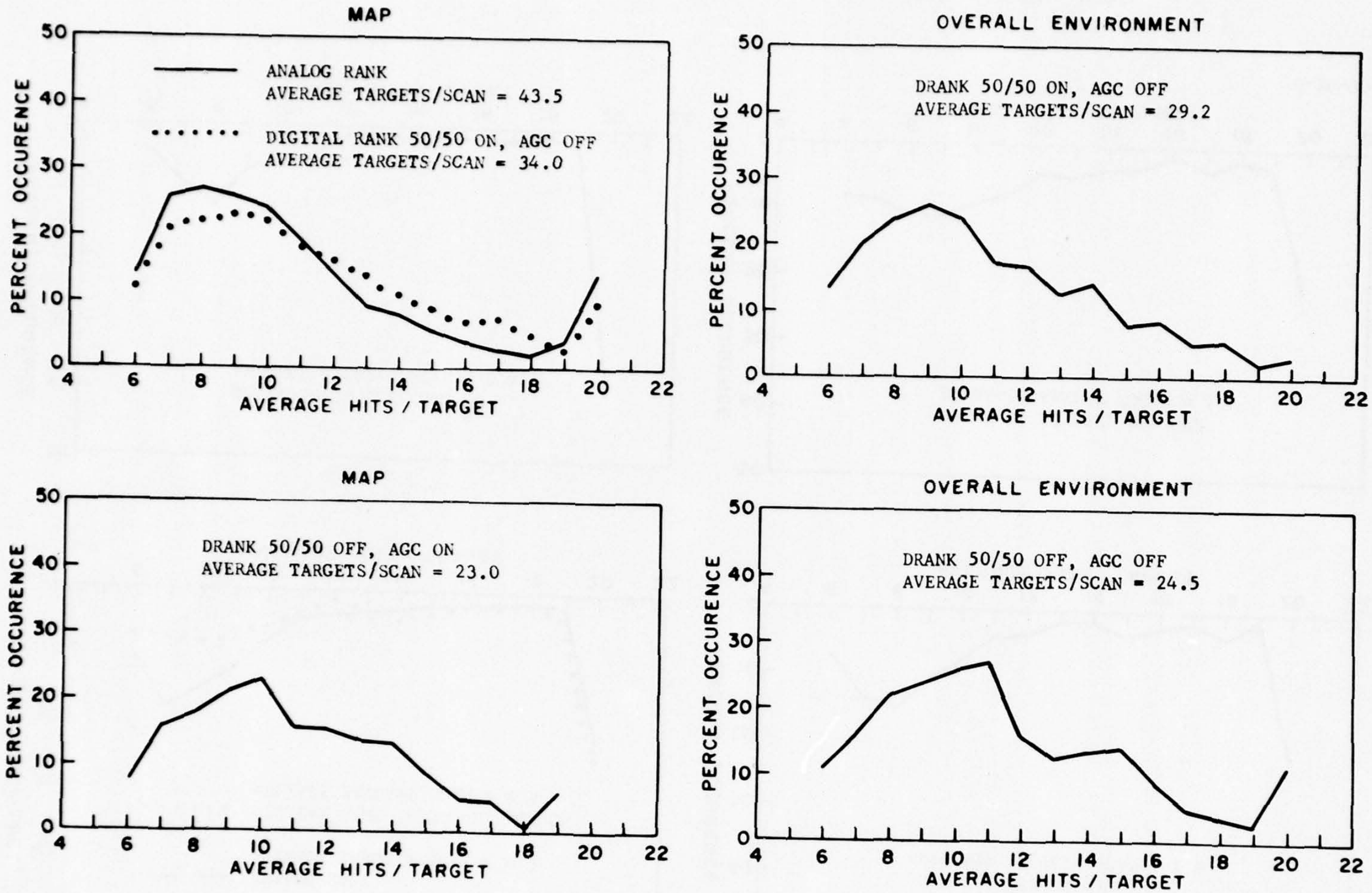

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FIGURE 31. TARGET HIT DISTRIBUTION, ASR-7 MTI, TAPE 3/12/75

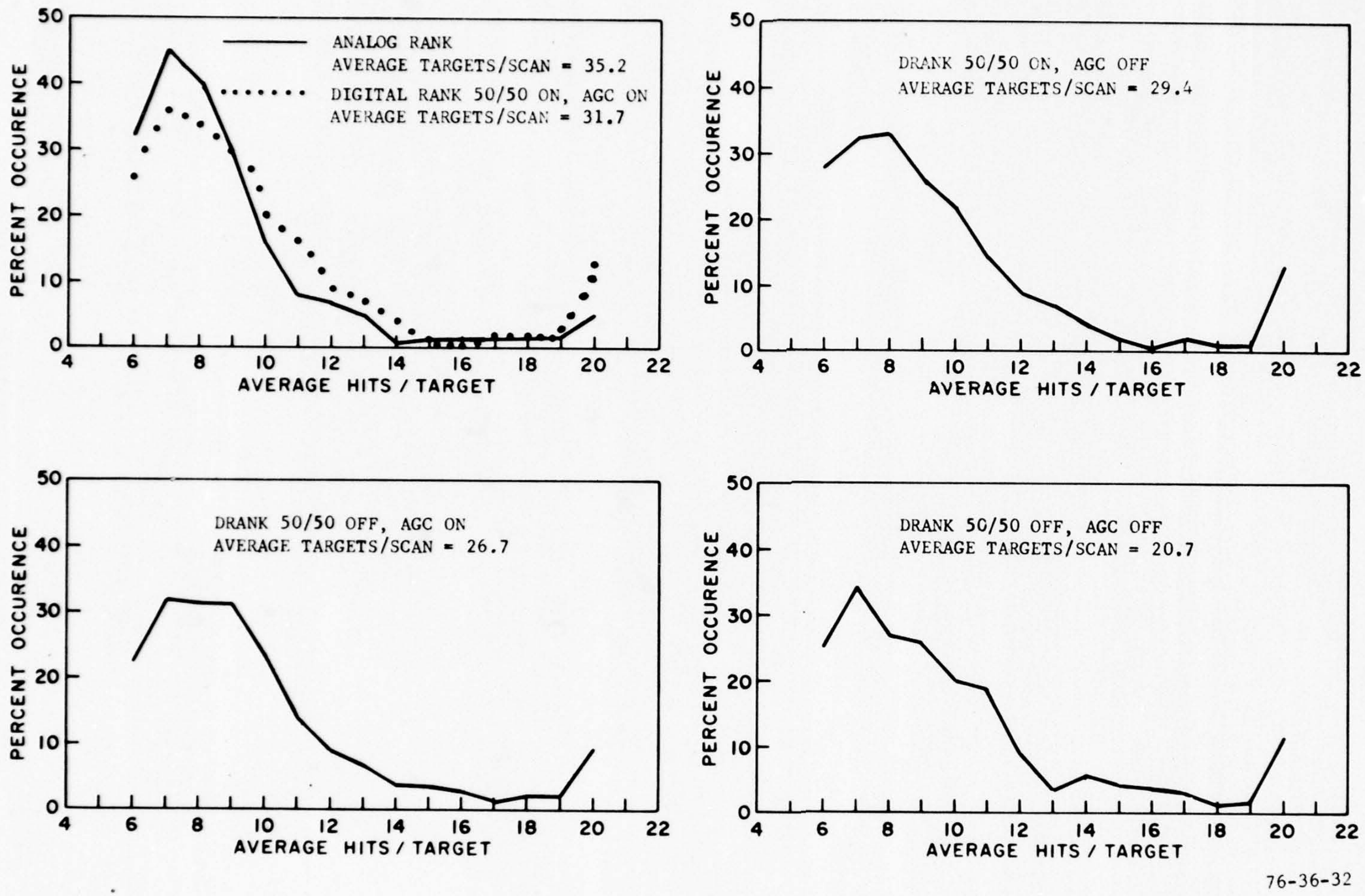

FIGURE 32. TARGET HIT DISTRIBUTION (ASR-7 MTI, TAPE 7/14/75 A.M.)

APPENDIX A

WEATHER PERCENT NOISE REGULATION

APPENDIX A

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

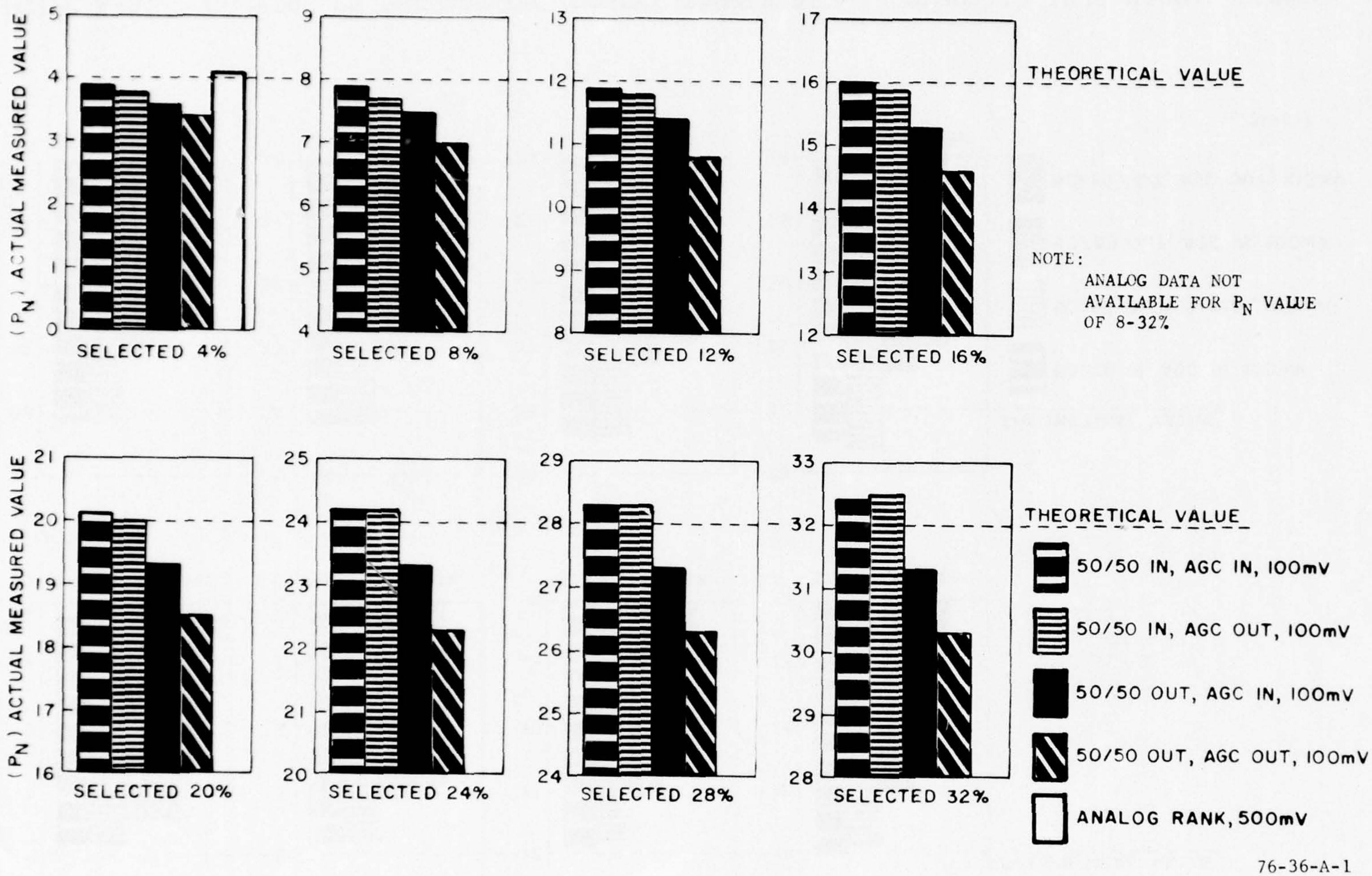

FIGURE A-1. CLUTTER PN REGULATION (DRANK) SAMPLE ASR-7, MARCH 12,1975 MTI VIDEO (500-mV INPUT NOISE)

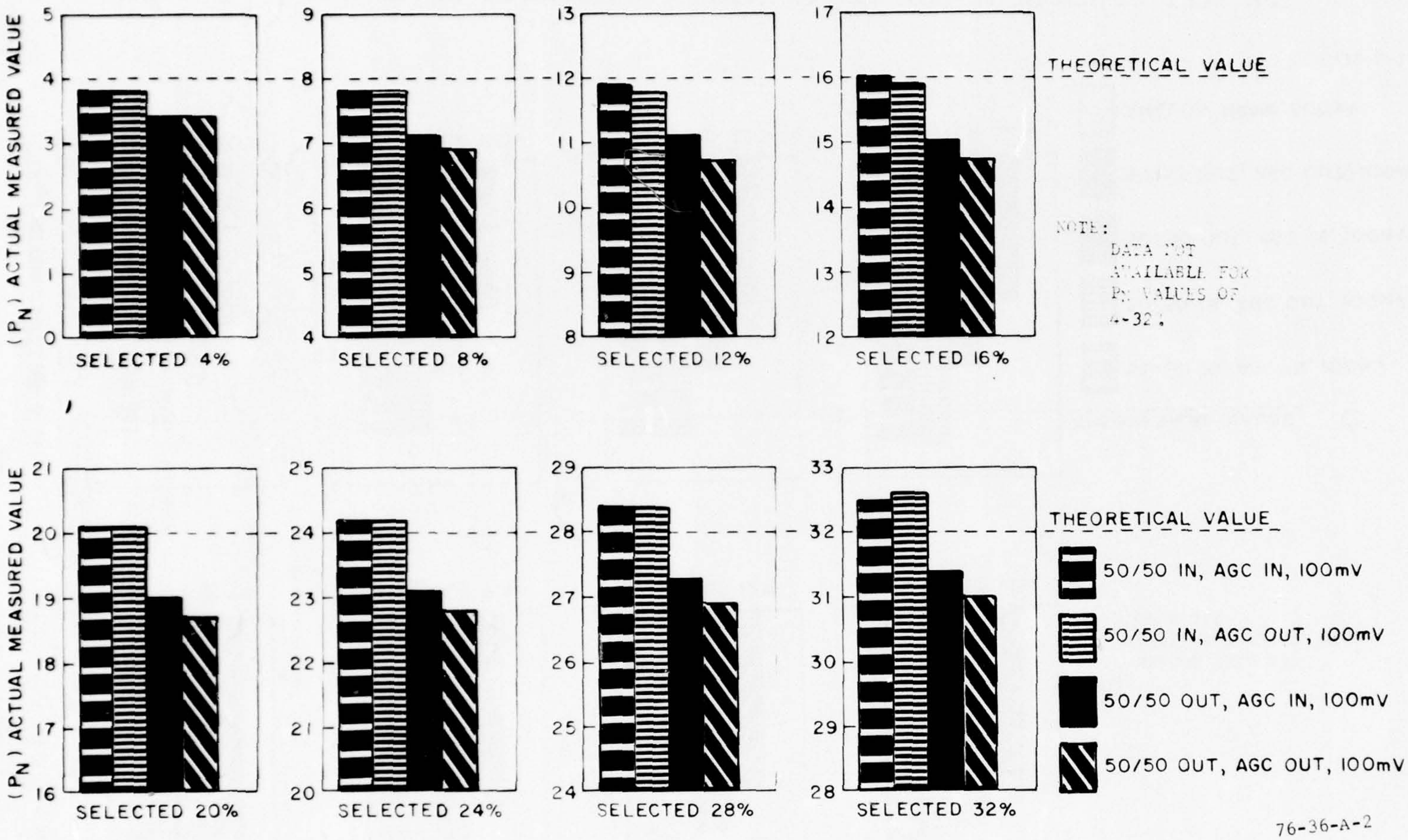

FIGURE A-2. CLUTTER PN REGULATION (DRANK) SAMPLE ASR-7, MARCH 12,1975 NORMAL VIDEO

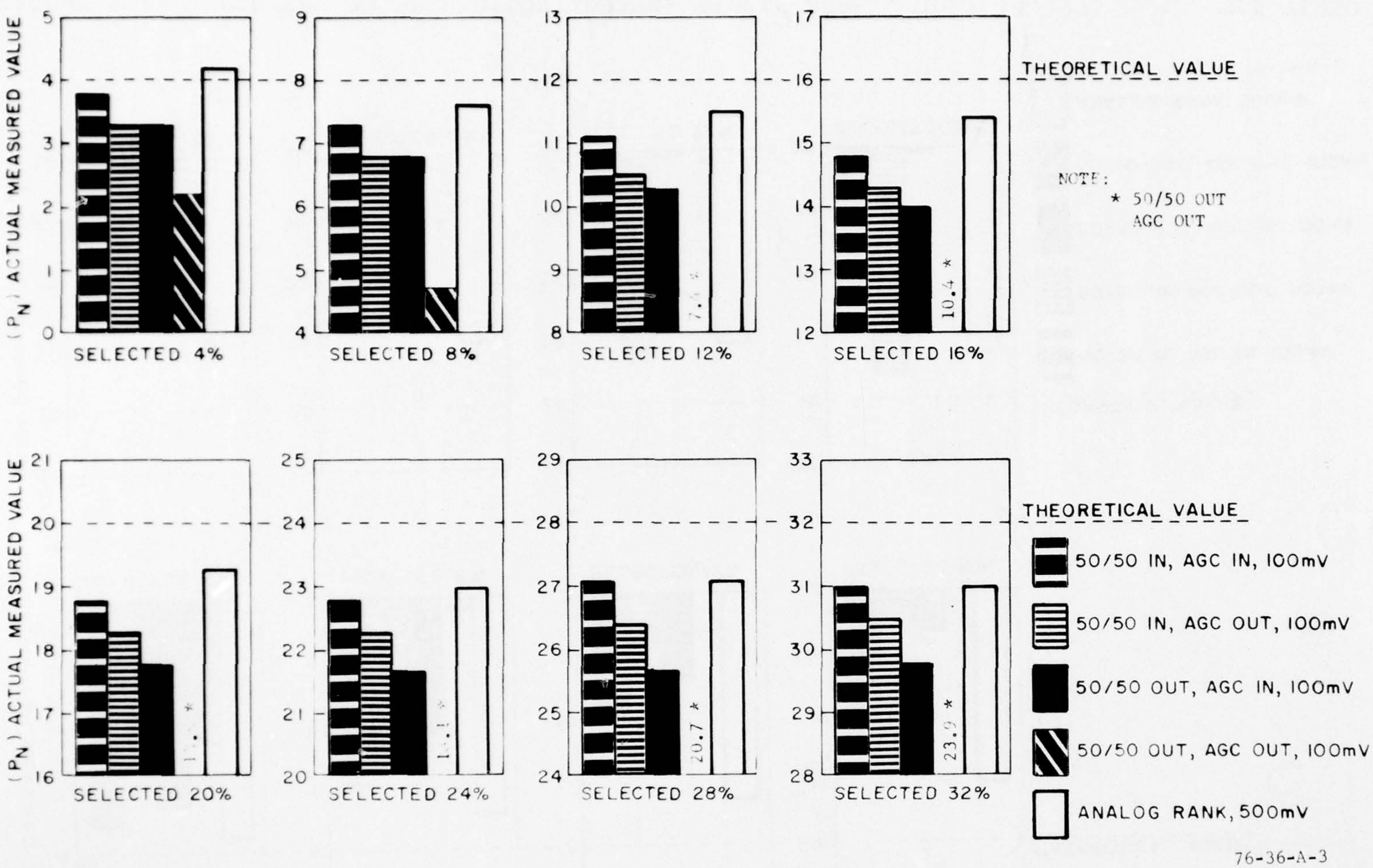

FIGURE A-3. CLUTTER PN REGULATION (DRANK) SAMPLE ASR-7, JULY 14, 1975, AM-NORMAL VIDEO

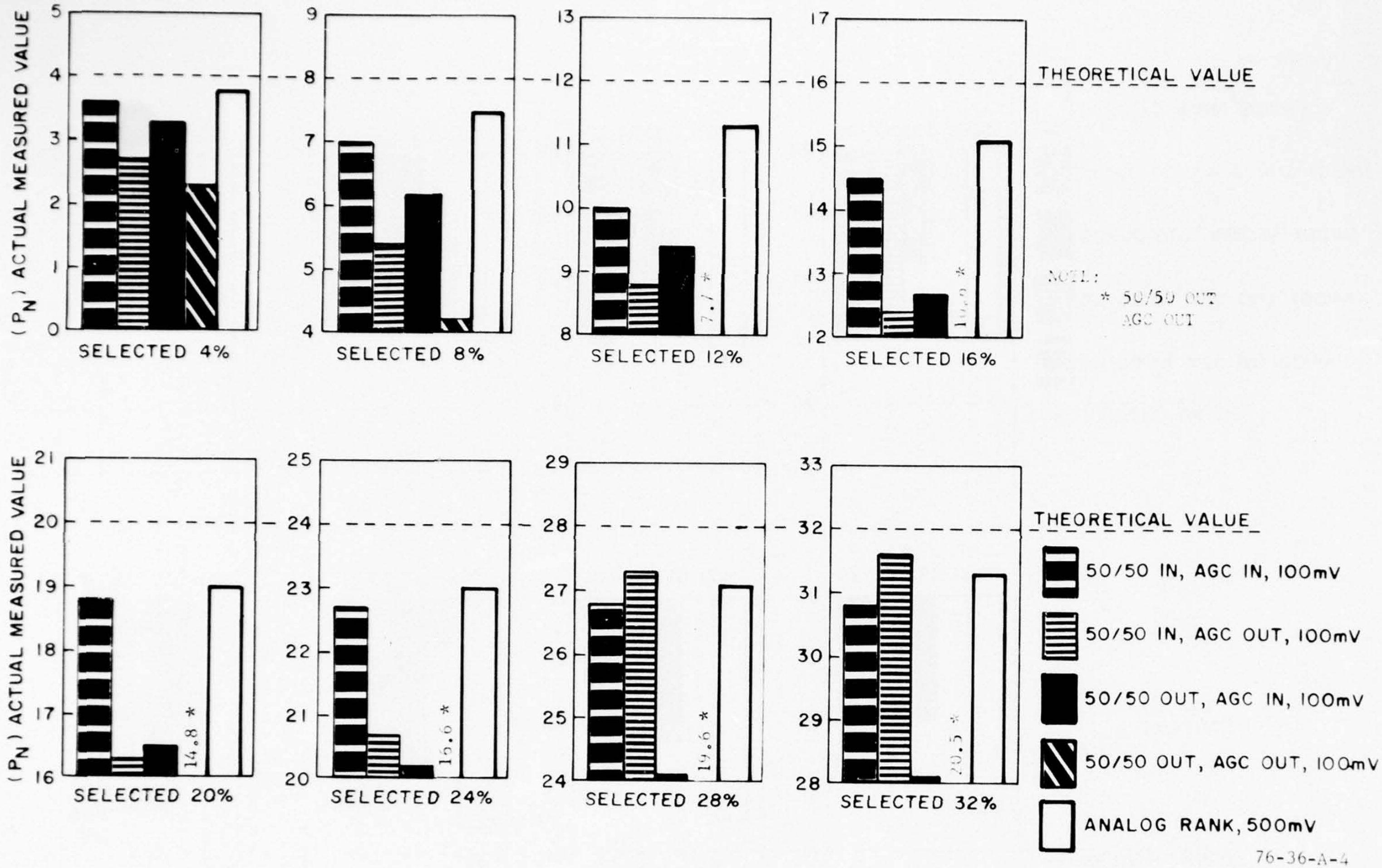

FIGURE A-4. CLUTTER PN REGULATION (DRANK) SAMPLE ASR-7, JULY 14,1975 A.M., MTI VIDEO

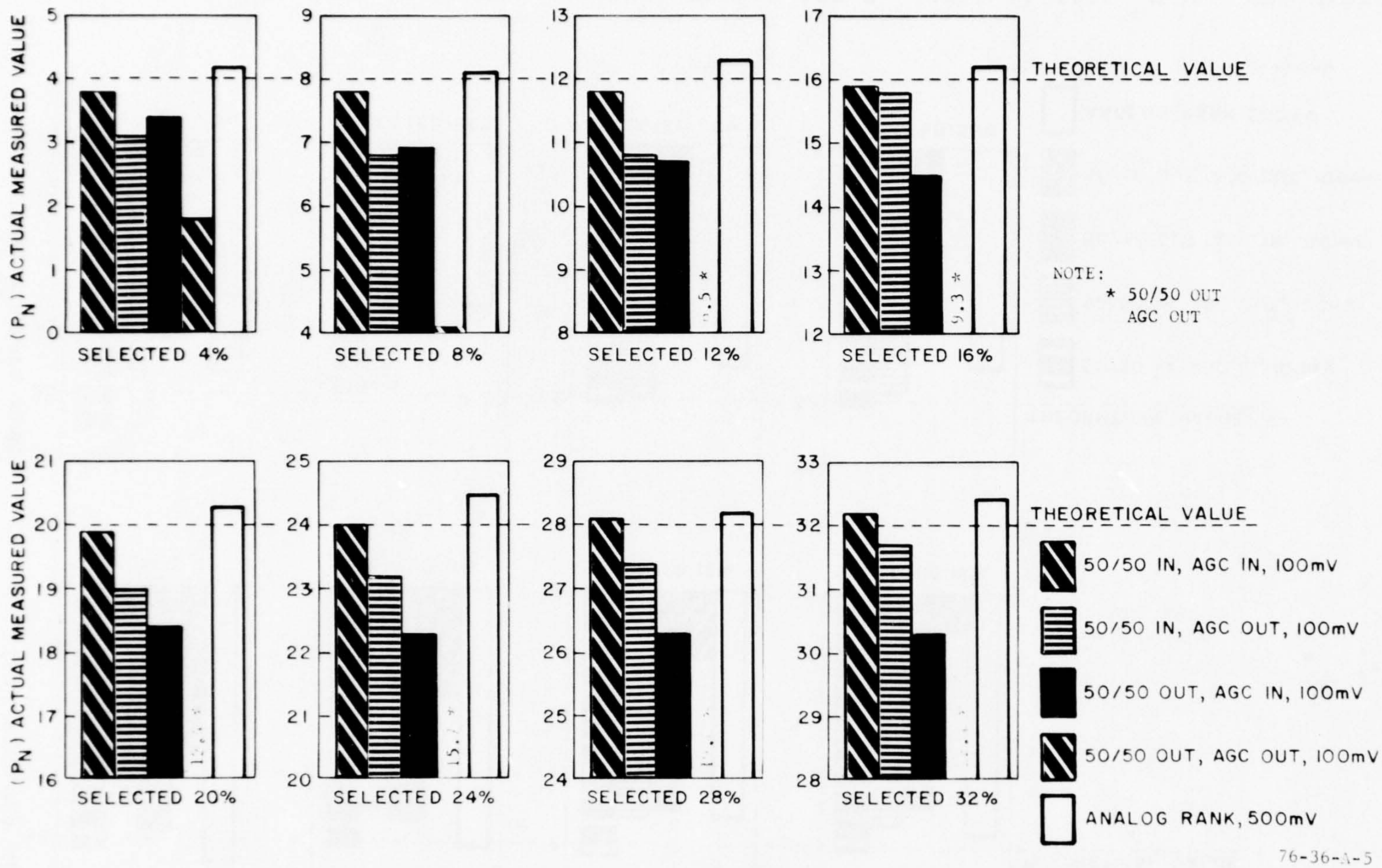

FIGURE A-5. CLUTTER REGULATION (PN)(DRANK) SAMPLE ASR-7, APRIL 15,1975, P.M., NORMAL VIDEO

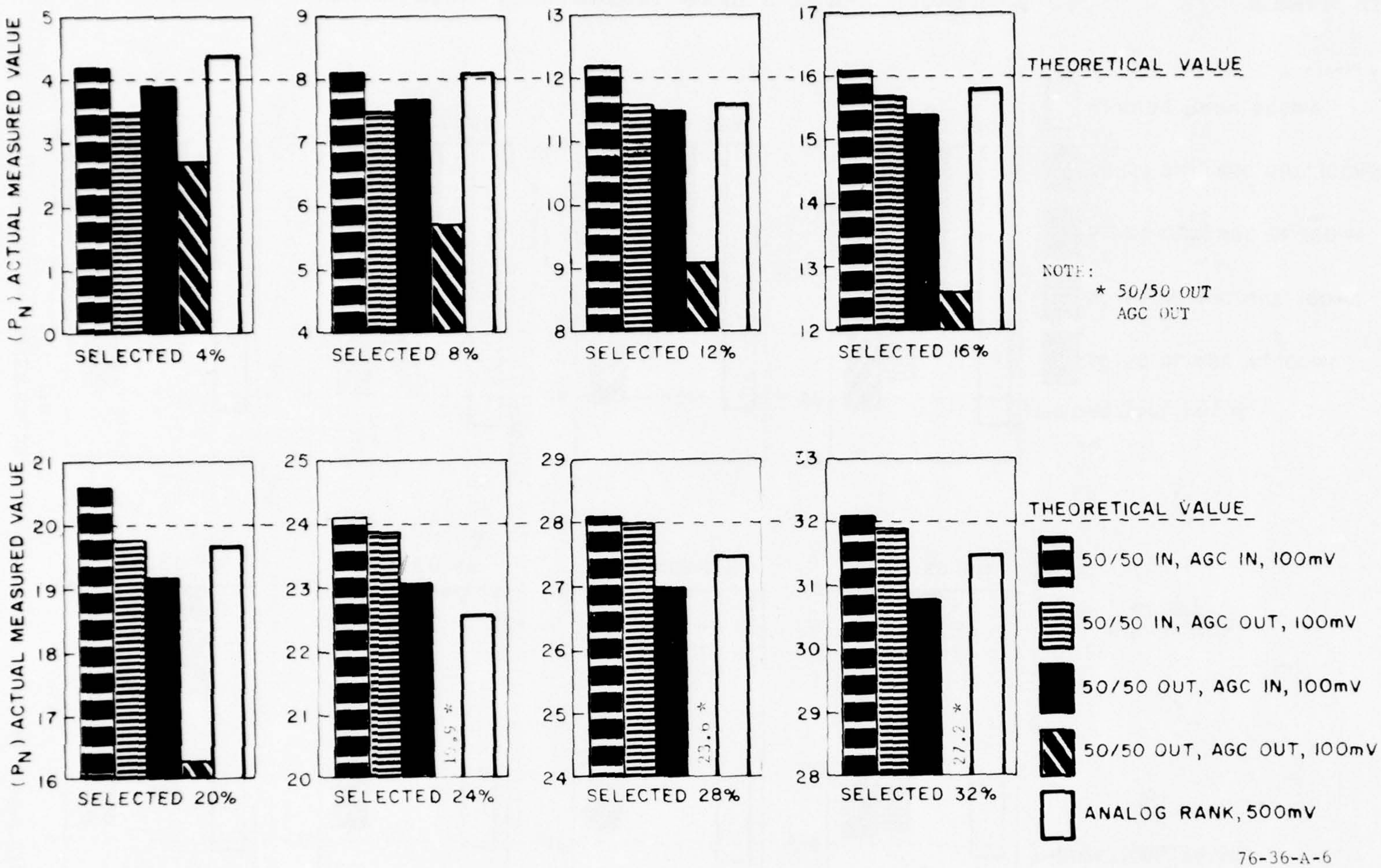

FIGURE A-6. CLUTTER PN REGULATION (DRANK) SAMPLE ASR-7, APRIL 15,1975, P.M., MTI VIDEO

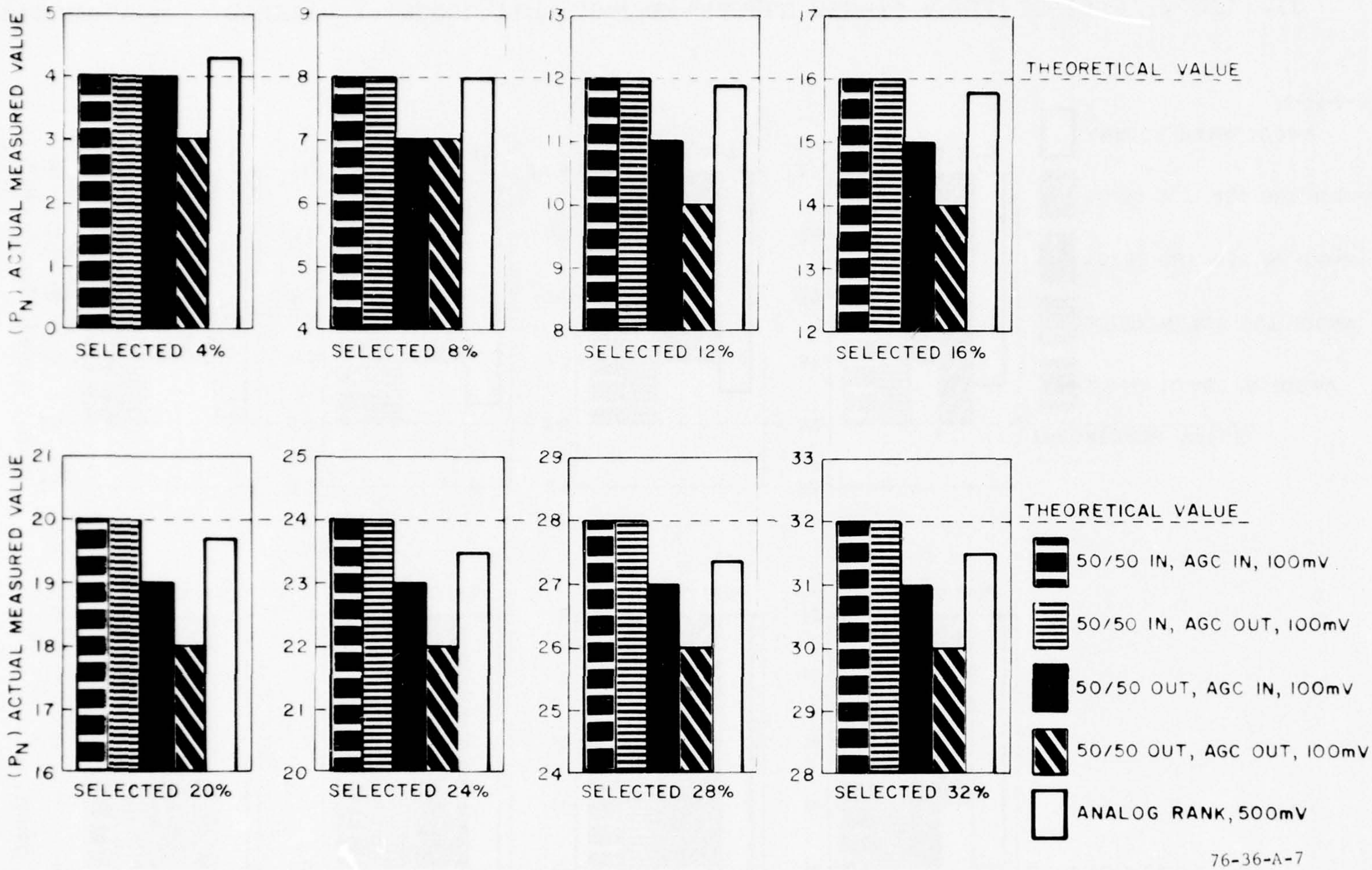

FIGURE A-7. CLUTTER PN REGULATION (DRANK) SAMPLE ASR-7, APRIL 15,1975, NORMAL VIDEO (500-mV INPUT NOISE)

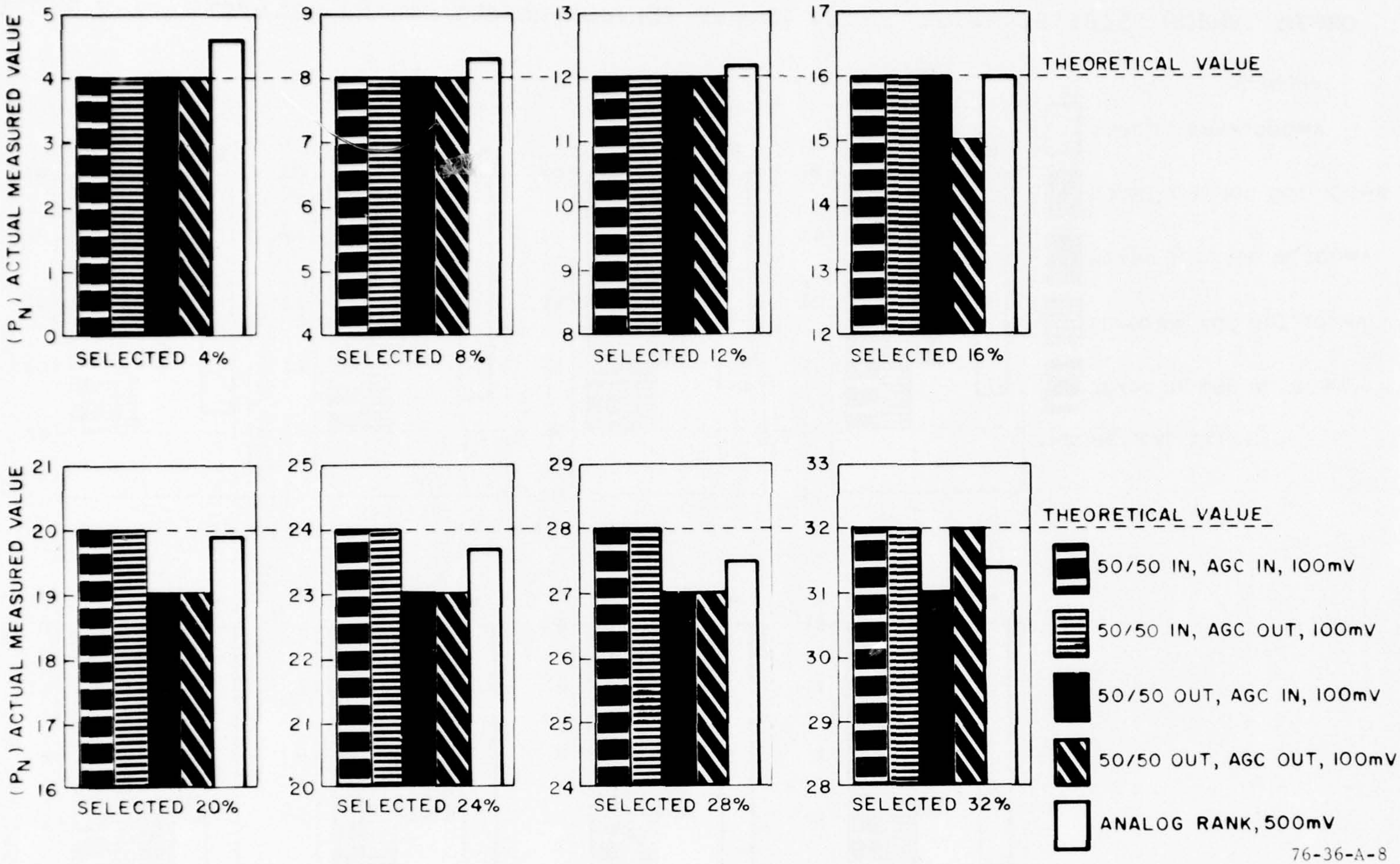

FIGURE A-8. CLUTTER PN REGULATION (DRANK) SAMPLE ASE-7, APRIL 15,1975, A.M., MTI VIDEO (500-mV INPUT NOISE)

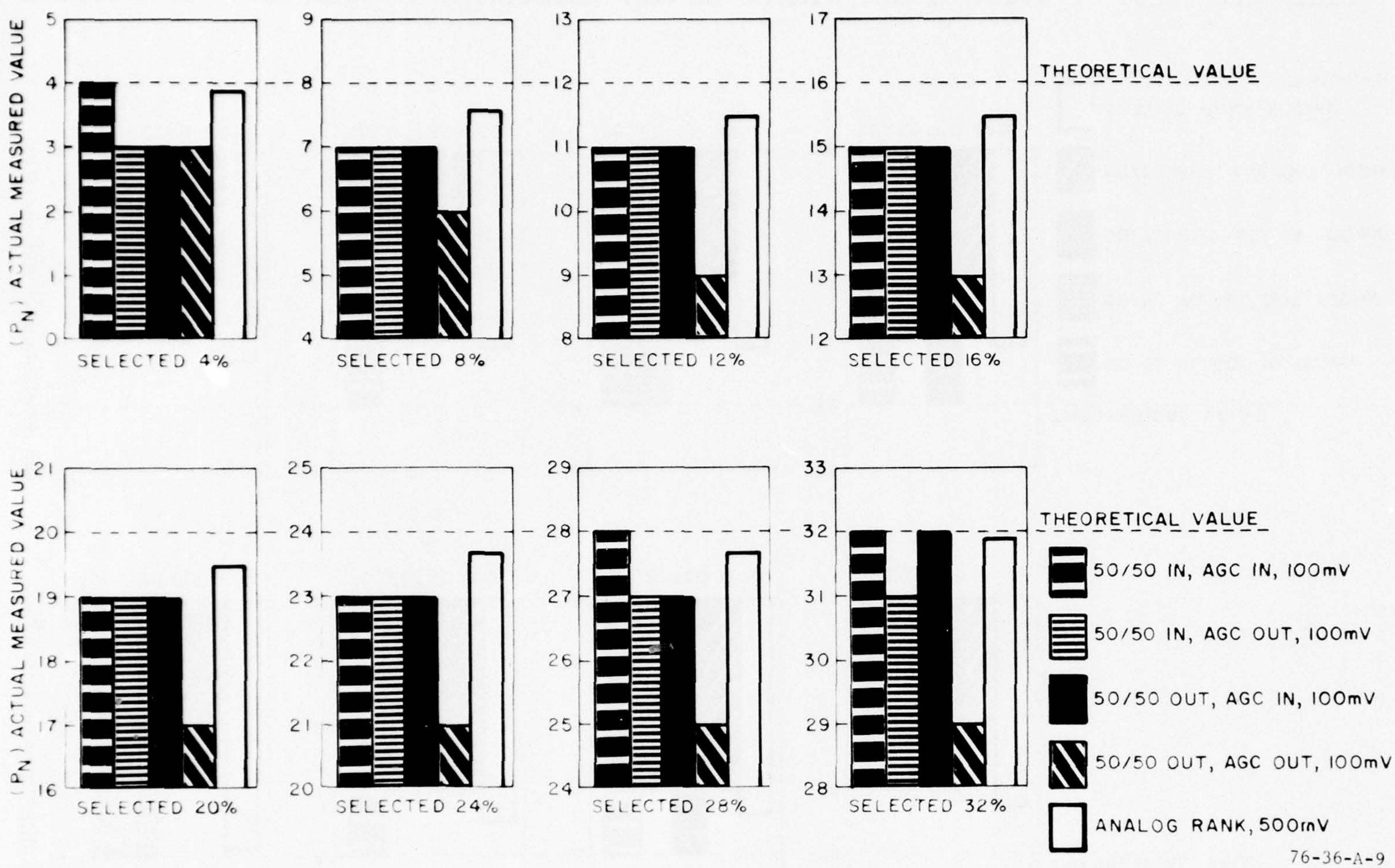

FIGURE A-9. CLUTTER PN REGULATION (DRANK) SAMPLE ASR-7, APRIL 3, 1975, NORMAL VIDEO (500-mV INPUT NOISE)

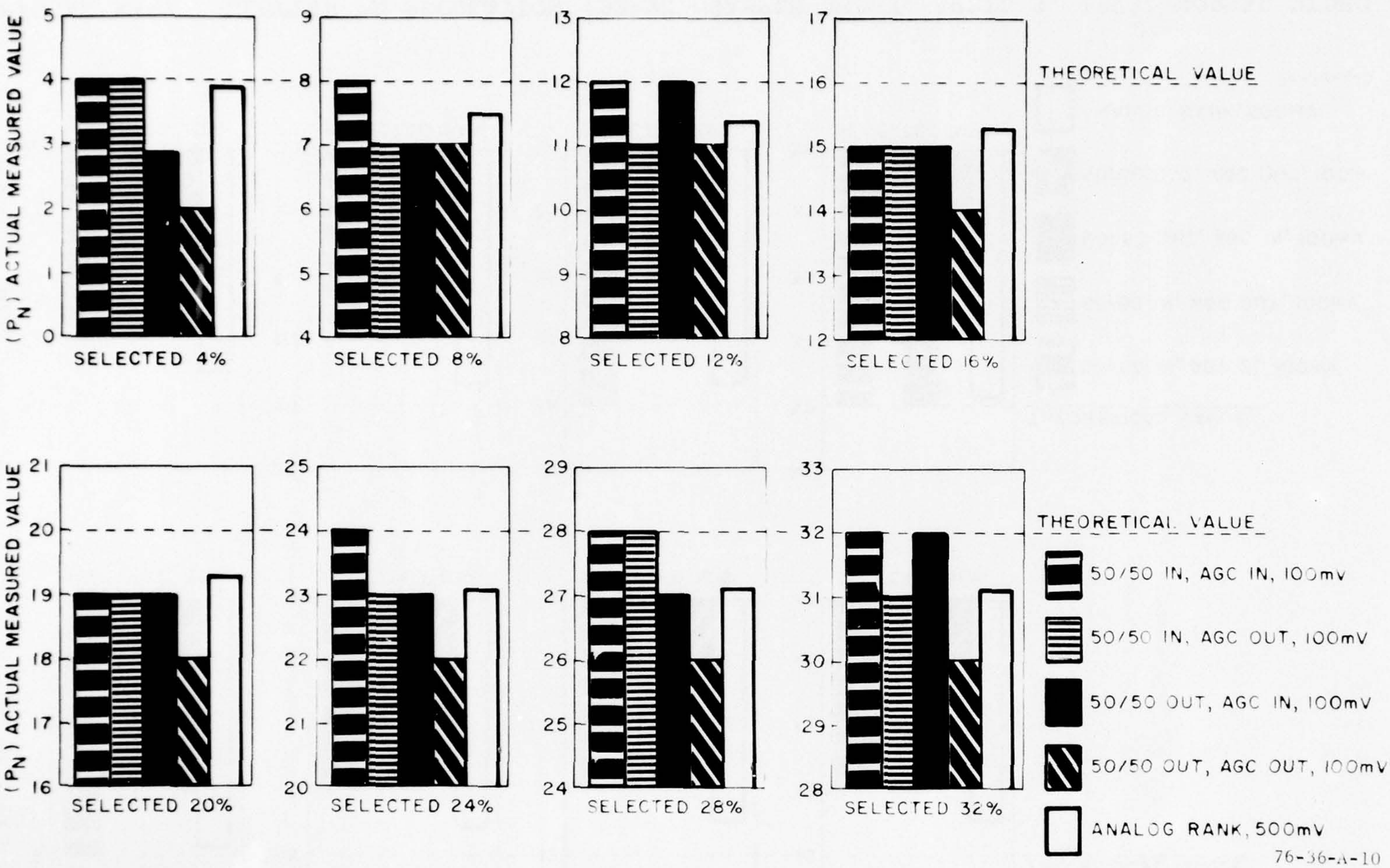

FIGURE A-10. CLUTTER PN REGULATION (DRANK) SAMPLE ASR-7, APRIL 3, 1975, MTI VIDEO (500-mV INPUT NOISE)

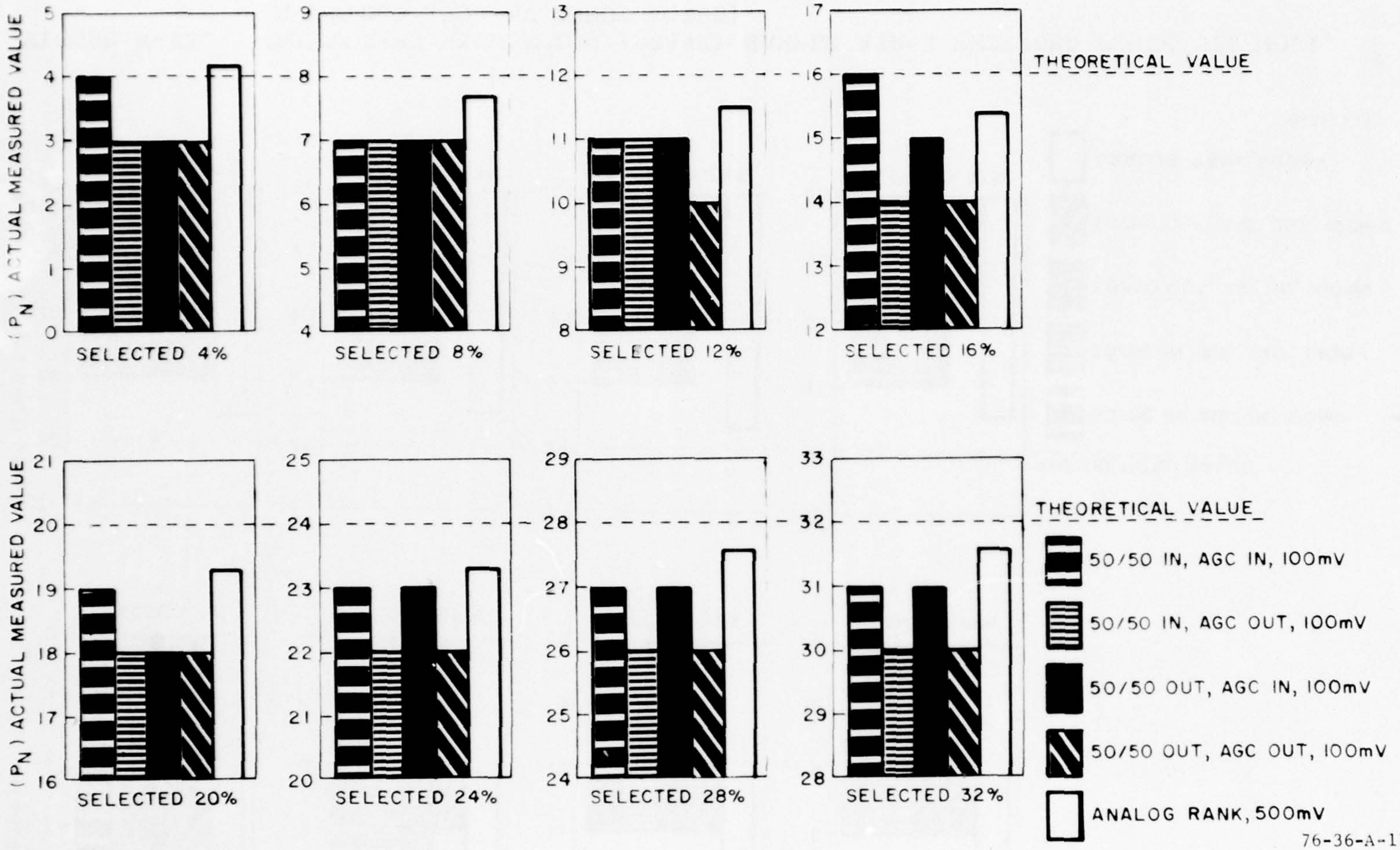

FIGURE A-11. CLUTTER PN REGULATION (DRANK) SAMPLE ASR-5 EXTENDED RANGE MTI NO.1, NORMAL VIDEO (500-mV INPUT NOISE)

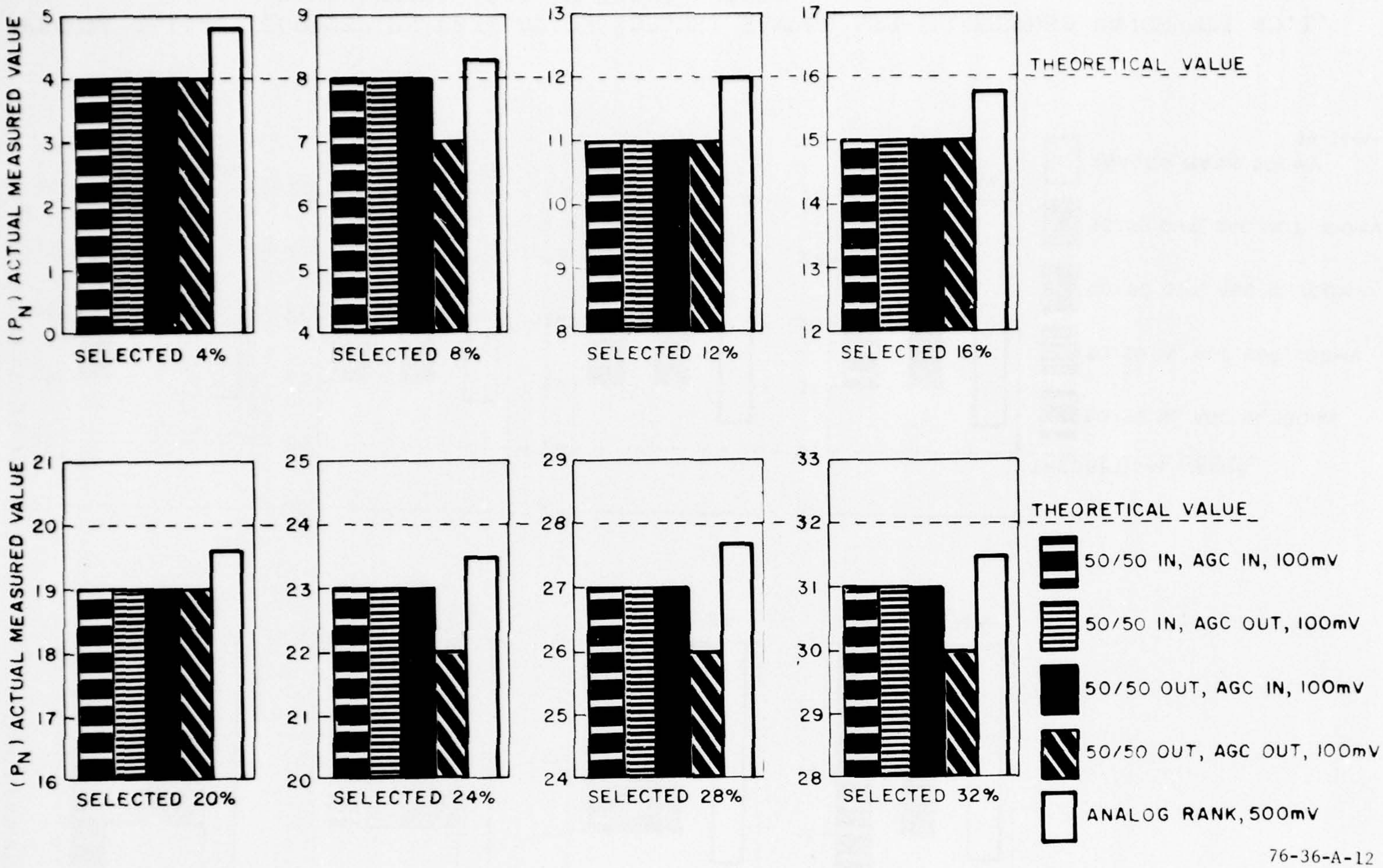

FIGURE A-12. CLUTTER PN REGULATION (DRANK) SAMPLE ASR-5 EXTENDED RANGE MTI NO.1, MTI VIDEO (500-mV INPUT NOISE)

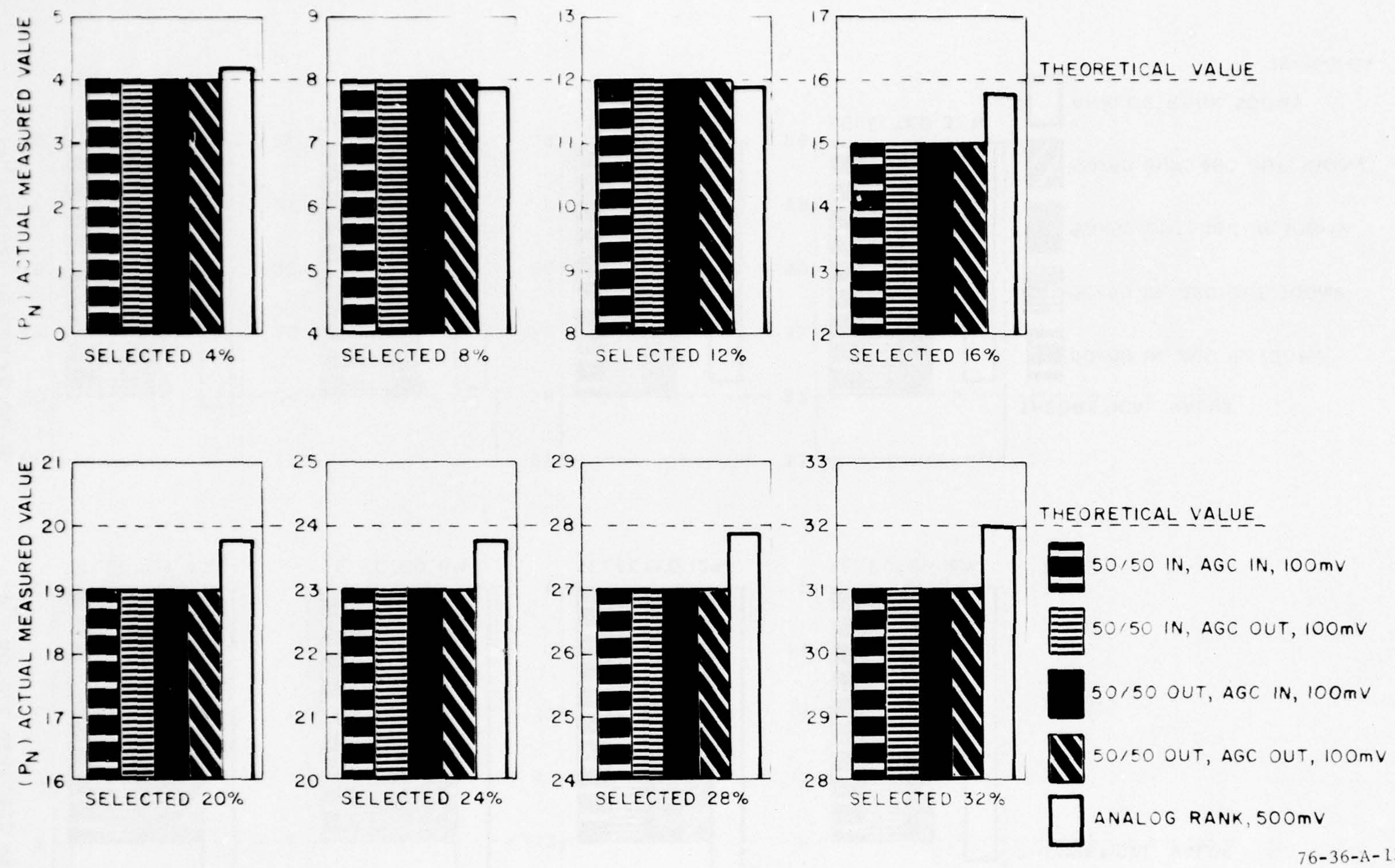

FIGURE A-13. CLUTTER PN REGULATION (DRANK) SAMPLE ASR-5 WW29 NORMAL VIDEO (500-mV INPUT NOISE)

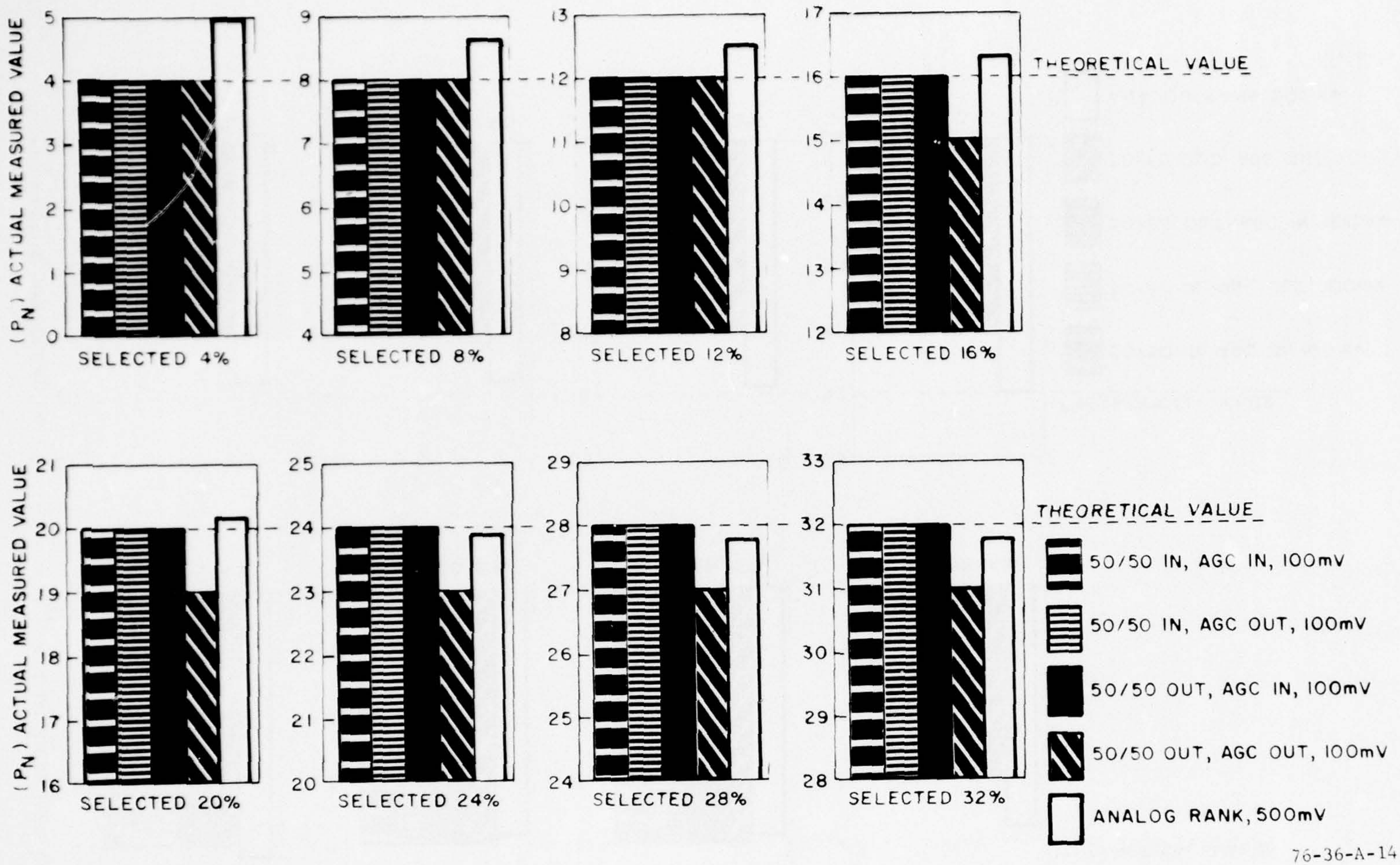

FIGURE A-14. CLUTTER PN REGULATION (DRANK) SAMPLE ASR-5 WW29, MTI VIDEO (500-mV INPUT NOISE)

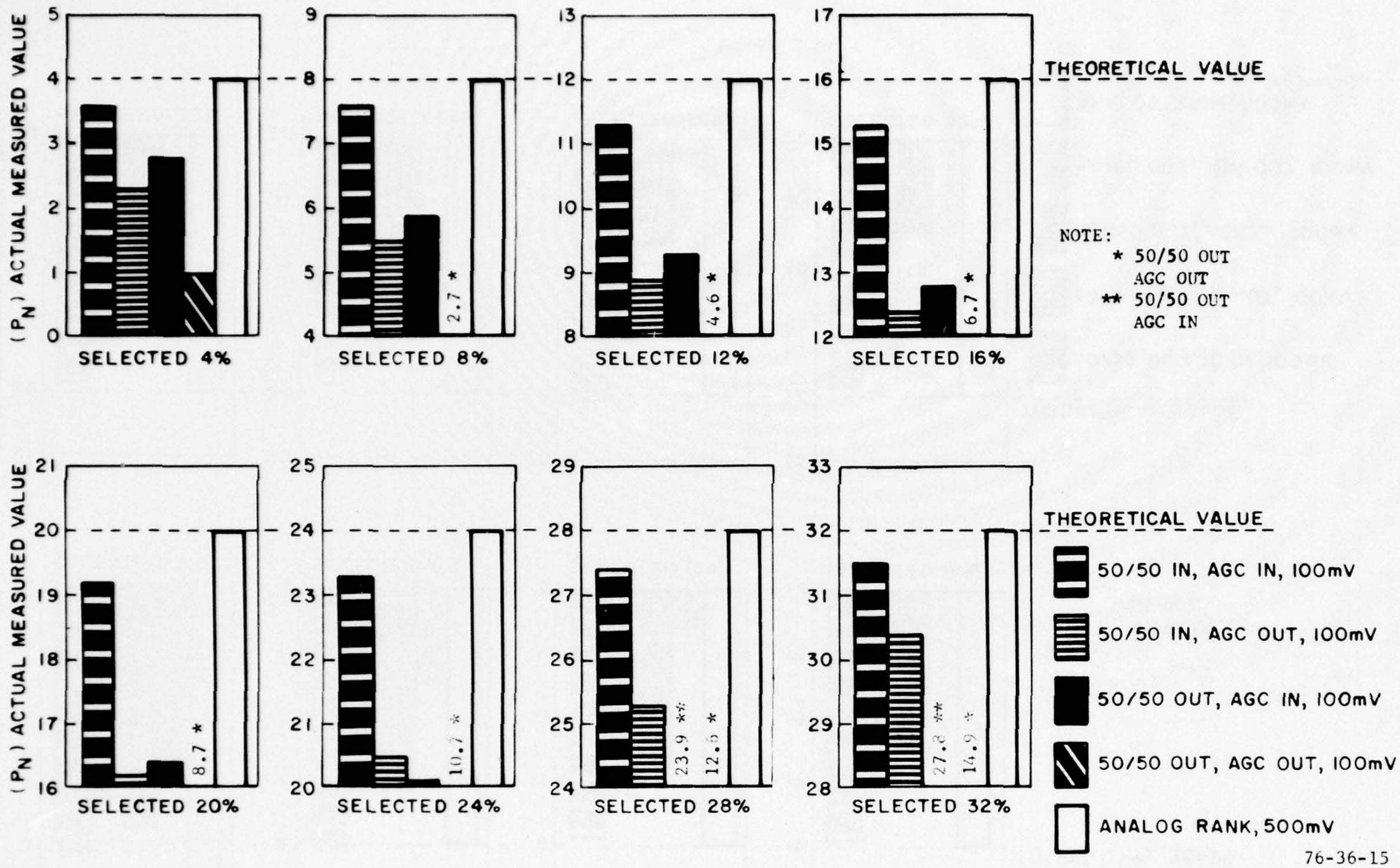

FIGURE A-15. CLUTTER PN REGULATION (DRANK) SAMPLE ASR-5, WW34, NORMAL VIDEO

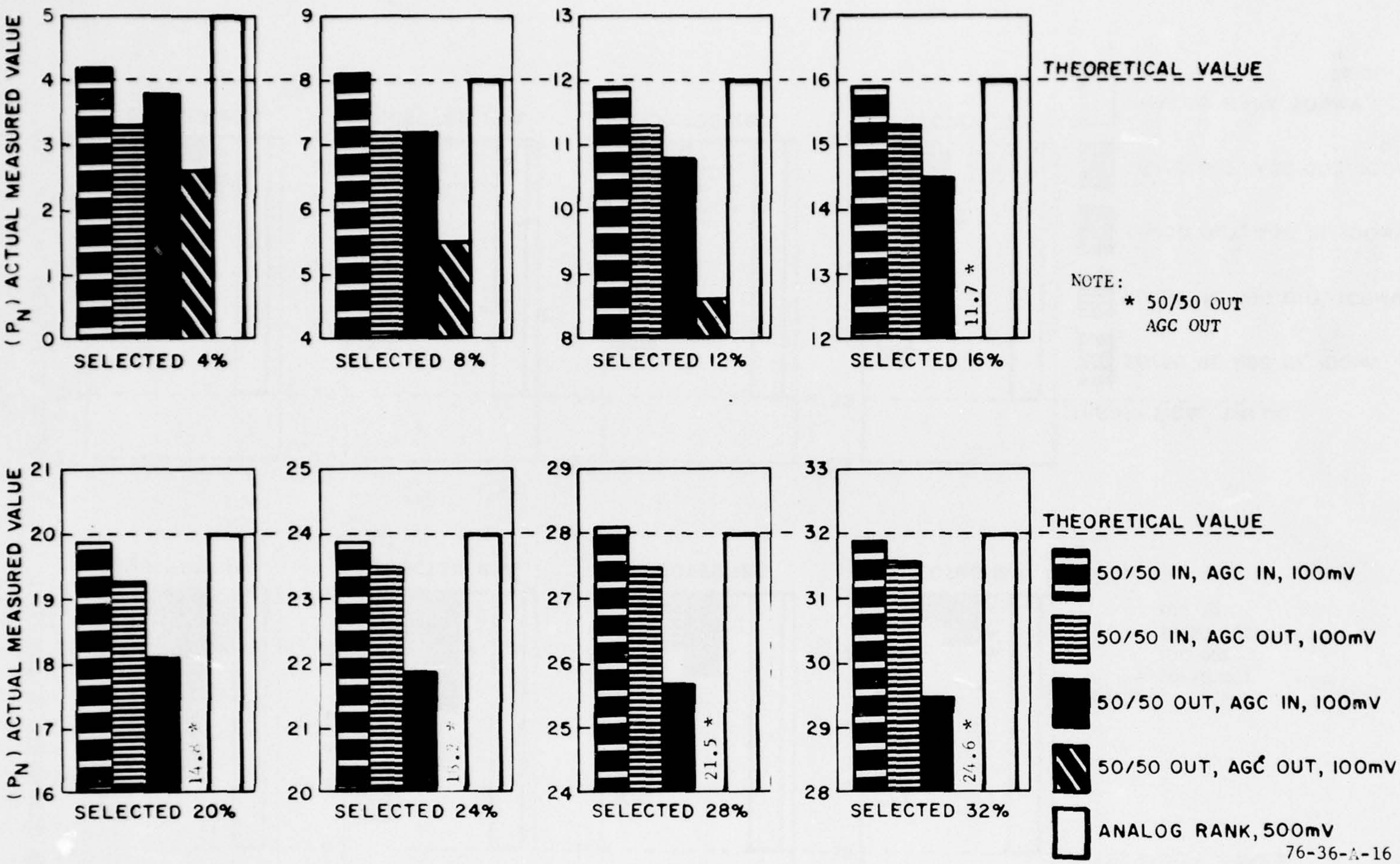

FIGURE A-16. CLUTTER PN REGUALTION (DRANK) SAMPLE ASR-5, WW34, MTI VIDEO

APPENDIX B

VIDEO SELECT MAPPING PERFORMANCE

APPENDIX B

LIST OF TABLES

TABLE B-1. VIDEO SELECT MAPPING PERFORMANCE

SAMPLE ASR-7 3/12/75 p.m.

	RANK QUANTIZER							
Run	Normal Channel	MTI Channel	50/50 Modification	AGC Modification	Notes	Percent	Targets	For
					Analog	8% PN		
1	Analog	Digital	In	In	Digital	4% PN	138.1	$3.21x10^{-5}$
2				Out			128.7	$2.99x10^{-5}$
3			Out	In			106.4	$2.47x10^{-5}$
4				Out			102.5	$2.38x10^{-5}$
					Digital	8% PN		
5	Digital	Analog	In	In	Analog	4% PN	243.1	$5.65x10^{-5}$
6				Out			206.9	$4.81x10^{-5}$
7			Out	In			170.0	$3.99x10^{-5}$
8				Out			171.7	$3.95x10^{-5}$
					MTI	4% PN		
9	Analog	Analog			Normal	8% PN	164.	$3.81x10^{-5}$

TABLE B-2. VIDEO SELECT MAPPING PERFORMANCE

SAMPLE ASR-7 7/14/75 a.m.

Run	RANK QUANTIZER Normal Channel	MTI Channel	50/50 Modification	AGC Modification	Notes Percent	No. of Targets	For
1	Analog	Digital	In	In	Analog 8 PN Digital 4 PN	234.3	5.44×10^{-5}
2				Out		239.1	5.55×10^{-5}
3			Out	In		186.8	4.33×10^{-5}
4				Out		195.6	4.52×10^{-5}
5	Digital	Analog	In	In	Digital 8% PN Analog 4 PN	256.4	5.95×10^{-5}
6				Out		234.8	5.45×10^{-5}
7			Out	In		233.0	5.41×10^{-5}
8				Out		212.7	4.94×10^{-5}
9	Analog	Analog			MTI 4 PN Normal 8% PN	197.	4.59×10^{-5}

TABLE B-3. VIDEO SELECT MAPPING PERFORMANCE

SAMPLE ASR-7 4/15/75 p.m.

Run	RANK QUANTIZER Normal Channel	RANK QUANTIZER MTI Channel	50/50 Modification	AGC Modification	Notes Percent	No. of Targets	For
1	Analog	Digital	In	In	Analog 8 PN Digital 4 PN	223.7	5.2×10^{-5}
2				Out		208.0	4.84×10^{-5}
3			Out	In		196.1	4.56×10^{-5}
4				Out		172.2	4.0×10^{-5}
5	Digital	Analog	In	In	Digital 8 PN Analog 4 PN	210.8	4.9×10^{-5}
6				Out		165.0	3.84×10^{-5}
7			Out	In		153.7	3.57×10^{-5}
8				Out		82.1	$1.9. \times 10^{-5}$
9	Analog	Analog	-	-	MTI 4 PN Normal 8 PN	108.	2.52×10^{-5}

TABLE B-4. VIDEO SELECT MAPPING PERFORMANCE

SAMPLE ASR-7 4/15/75 a.m.

Run	RANK QUANTIZER Normal Channel	RANK QUANTIZER MTI Channel	50/50 Modification	AGC Modification	Notes (Percent)	No. of Targets	For
1	Analog	Digital	In	In	Analog 8 PN Digital 8% PN		2.17×10^{-5}
2				Out		99.9	2.29×10^{-5}
3			Out	In		89.6	2.05×10^{-5}
4				Out		81.9	1.87×10^{-5}
5	Digital	Analog	In	In	Digital 8 PN Analog 4 PN	142.1	3.25×10^{-5}
6				Out		133.4	3.05×10^{-5}
7			Out	In		110.5	2.53×10^{-5}
8				Out		102.2	2.34×10^{-5}
9	Analog	Analog	-	-	MTI 4% PN Normal 8 PN	110.	2.55×10^{-5}

TABLE B-5. VIDEO SELECT MAPPING PERFORMANCE

SAMPLE ASR-7 4/3/75

Run	RANK QUANTIZER Normal Channel	RANK QUANTIZER MTI Channel	50/50 Modification	AGC Modification	Notes	No. of Targets	For
					Percent		
1	Analog	Digital	In	In	Analog 8 PN Digital 4 PN	83.1	1.75×10^{-5}
2				Out		89.7	1.89×10^{-5}
3			Out	In		69.3	1.45×10^{-5}
4				Out		77.6	1.63×10^{-5}
5	Digital	Analog	In	In	Digital 8 PN Analog 4 PN	108.2	2.28×10^{-5}
6				Out		100.2	2.11×10^{-5}
7			Out	In		86.7	1.83×10^{-5}
8				Out		76.7	1.62×10^{-5}
9	Analog	Analog	-	-	MTI 4 PN Normal 8 PN	98.9	2.3×10^{-5}

TABLE B-6. VIDEO SELECT MAPPING PERFORMANCE

SAMPLE ASR-5 WW29

Run	RANK QUANTIZER Normal Channel	RANK QUANTIZER MTI Channel	50/50 Modification	AGC Modification	Notes	No. of Targets	For
					Percent		
					Analog 8 PN		
1	Analog	Digital	In	In	Digital 4 PN	103.2	$4.57x10^{-5}$
2				Out		99.9	$4.42x10^{-5}$
3			Out	In		98.6	$4.36x10^{-5}$
4				Out		93.2	$4.12x10^{-5}$
					Digital 8 PN		
5	Digital	Analog	In	In	Analog 4 PN	114.6	$5.07x10^{-5}$
6				Out		129.7	$5.74x10^{-5}$
7			Out	In		115.8	$5.12x10^{-5}$
8				Out		126.3	$5.59x10^{-5}$
					MTI 4 PN		
9	Analog	Analog	-	-	Normal 8 PN	131.	$5.78x10^{-5}$